PROCEEDINGS OF THE GEOLOGISTS' ASSOCIATION

QE
1
G5
vol. 65
1954/55

VOLUME SIXTY-FIVE : 1954-5

EDITED BY A. J. DOLLAR

Authors alone are responsible for the opinions
and facts stated in their respective papers, and for the
accuracy of their references

COLCHESTER
BENHAM AND COMPANY LIMITED
1954-5

Officers and Council

1954

President: L. R. COX, M.A., SC.D., F.R.S., F.G.S.

Vice-Presidents: D. WILLIAMS, D.SC., PH.D., B.E., F G.S.; A. J. BUTLER, O.B.E., M.SC., F.G.S.; T. EASTWOOD, A.R.C.S., M.I.M.M., F.G.S., H. DIGHTON THOMAS, M.A., PH.D., F.G.S., G. W. HIMUS, PH.D , F.G.S.

Treasurer: L. J. PITT, F.G.S., 1, Lancaster Road, North Harrow, Middlesex.

Secretaries:

General: R. REELEY, F.G.S., Geological Survey and Museum, South Kensington, S.W.7.

Field Meetings: S. W. HESTER, F.G.S., Geological Survey and Museum, South Kensington, S.W.7.

Publications Committee: W. E. SWINTON, B.SC., PH.D., F.G.S., F M.A., British Museum (Nat. Hist.), South Kensington, S.W.7, succeeded by M. K. WELLS, M.SC., PH.D., F.G.S., Department of Geology, University College, Gower Street, London, W.C.1.

Editor: C. D. OVEY, B.SC., M.A., F.G.S., F.R.MET.S., Department of Geography, Downing Place, Cambridge, succeeded by A. J. DOLLAR, PH.D., A.K.C., F.R.S.E., F.G.S., Department of Geology, Birkbeck College, Malet Street, London, W.C.1.

Librarian: R. BRADSHAW, M.SC., F.G.S., Department of Geology, University College, Gower Street, London, W.C.1.

Other Members of the Council:

B. AINSLEY, F.G.S. (1951)
S. BRACEWELL, B.SC., D.I.C., A.R.C.S., F.G S. (1953)
D. CURRY, M.A., F.G.S. (1953)
Mrs. E. M. EVANS, M.SC., F.G.S. (1954)
Mrs. V. A. EYLES, B.SC., F.G.S. (1952)
A. F. HALLIMOND, M.A., SC.D., F.G.S (1952)
Mrs. J. V. HARRISON, M.A., B.SC. (1954)
Mrs. H. K. HAWKES, M.SC., F.G.S. (1951)
E. C. MARTIN, O.B.E., B.SC., A R.I.C., F.G.S. (1952)
W. E. SMITH, M.SC., F.G.S. (1953)
GILBERT WILSON, PH.D., M.SC., D.I.C., F.G.S. (1954)

Contents

Page
Annual Report of the Council 64
AGER, D. V. The Genus *Gibbirhynchia* in the British Domerian ... 25
ARKELL, W. J. Three Complete Sections of the Cornbrash 115
BADEN-POWELL, D. F. W. Note on the age of the Holderness shells (Summer Field Meeting in East Yorkshire: Appendix B) ... 327
BISAT, W. S., VERNON WILSON, C. W. WRIGHT, J. E. HEMINGWAY & H. C. VERSEY. Summer Field Meeting in East Yorkshire ... 313
————. Additional records of mollusca from the Dimlington area, and the relation of the beds to the Bridlington Crag (Report on Summer Field Meeting in East Yorkshire: Appendix A) ... 325
BISHOP, A. C. & A. K. WELLS. The Origin of Aplites 95
BLYTH, F. G. H. The southern margin of the Cairnsmore of Fleet granite at the Clints of Dromore, Galloway 224
BOWEN, R. N. C. Foraminifera from the London Clay 125
BRADSHAW, R. Field Meeting in the Caterham–Godstone District ... 23
————, M. ROQUES & P. LAPADU-HARGUES. Summer Field Meeting in the Massif Central 278
BURCHELL, J. P. T. Loessic Deposits in the Fifty-foot Terrace post-dating the Main Coombe Rock of Baker's Hole, Northfleet, Kent 256
CARRECK, J. N. & A. G. DAVIS. Field Meeting at Keston, Downe, Kent, and Visit to the Darwin Memorial Rooms at Downe House 338
———— & M. P. KERNEY. Notes on some Holocene Chalk Rain-washes at Cudham and Keston, near Downe, Kent (Appendix to Report on Field Meeting at Keston, Downe, Kent) 340
CASEY, R. *Falciferella*, a new genus of Gault Ammonites, with a review of the family Aconeceratidae in the British Cretaceous ... 262
CLARKE, B. B. & J. D. LAWSON. Field Meeting at Hereford (Midland Group) 374
COLEMAN, A. The Relief and Drainage Evolution of the Blean ... 52
CURRY, D. Field Meeting at Whitecliffe Bay, Isle of Wight 182

Page

Davis, A. G. & J. N. Carreck. Field Meeting at Keston, Downe, Kent, and Visit to the Darwin Memorial Rooms at Downe House 338

——— & G. F. Elliott. Field Meeting in Sheppey 383

Elliott, G. F. & A. G. Davis. Field Meeting in Sheppey 383

Elliott, G. F. Note on the varying condition of the Sheppey Cliffs and Foreshore (Appendix to Report on Field Meeting in Sheppey) 384

Evans, P. Field Meeting in the Vale of St. Albans 18

Fairbairn, P. E. A Temporary Exposure in the Bracklesham Beds near Sopley, Hampshire 251

Firman, R. J. Note on Metasomatic changes in the rocks adjacent to the Shap Granite (Appendix to The Geology of the Lake District—a review) 412

Garrett, P. A. Field Meeting at Abberley, Worcestershire (Midland Group) 372

Griffith, J. A Technique for the Removal of Skeletal Remains from Bone-Bed 123

Hardie, W. G. The Silurian Rocks of Kendal End, near Barnt Green, Worcestershire 11

Hemingway, J. E., Vernon Wilson, C. W. Wright, H. C. Versey & W. S. Bisat. Summer Field Meeting in East Yorkshire ... 313

Himus, G. W. The Geologists' Association and its Field Meetings. Presidential Address 1

Hollingworth, S. E. The Geology of the Lake District—a review... 385

——— and Others. Summer Field Meeting in the Lake District 415

Kerney, M. P. & J. N. Carreck. Notes on some Holocene Chalk Rainwashes at Cudham and Keston, near Downe, Kent (Appendix to Report on Field Meeting at Keston, Downe, Kent) ... 340

Kirkaldy, J. F. & F. A. Middlemiss. Field Meeting in the Hindhead Neighbourhood 175

Kidson, C. & Scott Simpson. Field Meeting, Whitsun 1953, at Lynton, North Devon 178

Page

Lapadu-Hargues, P., M. Roques & R. Bradshaw. Summer Field Meeting in the Massif Central 278

Lawson, J. D. & B. B. Clarke. Field Meeting at Hereford (Midland Group) 374

McIntyre, D. B. The Moine Thrust—its discovery, age and tectonic significance 203

Martin, E. C. Field Meeting at Highdown Hill, Clapham, and Storrington, West Sussex 377

Middlemiss, F. A. & J. F. Kirkaldy. Field Meeting in the Hindhead Neighbourhood 175

Milbourne, R. A. Field Meeting at Sevenoaks, Kent 426

Oliver, R. L. Note on the Succession in the region around the head of Borrowdale, Cumberland (Appendix to The Geology of the Lake District—a review) 407

Pitcher, W. S. & R. L. Cheesman. Summer Field Meeting in North-West Ireland with an Introductory Note on the Geology ... 345

Roques, M., Lapadu-Hargues & R. Bradshaw. Summer Field Meeting in the Massif Central 278

Rose, W. C. C. The Sequence and Structure of the Skiddaw Slates in the Keswick–Buttermere Area (Appendix to The Geology of the Lake District—a review) 403

Simpson, Brian. Field Meeting in South Wales 328

————, Scott & C. Kidson. Field Meeting, Whitsun 1953, at Lynton, North Devon 178

Versey, H. C., Vernon Wilson, C. W. Wright, J. E. Hemingway & W. S. Bisat. Summer Field Meeting in East Yorkshire 313

Wells, A. K. & A. C. Bishop. The Origin of Aplites 95

Wells, M. K. Summer Field Meeting in the Lake District 415

Wilson, Vernon, C. W. Wright, J. E. Hemingway, H. C. Versey & W. S. Bisat. Summer Field Meeting in East Yorkshire ... 313

Worrall, G. A. The Lower Greensand in East Kent 185

Wright, C. W., Vernon Wilson, J. E. Hemingway, H. C. Versey & W. S. Bisat. Summer Field Meeting in East Yorkshire ... 313

List of Plates

PLATE — Facing Page

1. *Gibbirhynchia* from British Domerian 36
2. A. Stepped surface, Anthony's Quarry, Dulverton 180
   B. Lynmouth and Lynton 180
3. Whitecliff Bay, viewed from Culver Cliff... 184
4. Boughton Quarry, near Maidstone, showing about 18 ft. of 'callow' overlying rag and hassock 196
5. A. The Clints of Dromore, looking towards the Deep Nick (centre) 248
   B. Eastern end of the Clints of Dromore, near Gatehouse-of-Fleet Station 248
6. A. Map of Granite boundary at the Clints of Dromore ... 248
   B. Details of rocks exposed at railway cutting, Dromore ... 248
7. British Aconeceratidae 276
8. A. Lac d'Aydat dammed by lava flow from Puy de la Vache ... 296
   B. Puy de Lassolas and Puy de la Vache. Breached cones at the south end of the chain of Puys 296
9. Pic de Sancy. Dykes of trachyte (Sancyite) in Cinérite à blocs ... 297
10. A. Upper Drab Clay with vertical jointing resting on Middle Drab Clay at Great Cowden, 6000 yards south of Hornsea sea wall 322
    B. Base of Lower Drab Clay, well-bedded and with pale and dark banding, resting on Sub Dry Clay at Moor Hill, Skirlington, three-quarters of a mile north of Atwick road end, north of Hornsea 322
11. A. The Boulder Bed, Croaghan Hill 370
    B. Xenolithic quartz-diorite, Kilclooney 370
12. A. A variety of 'owharoite', Ignimbrite, from Owharoa, North Island, New Zealand 408
    B. Ignimbrite tuff of rhyolite or rhyodasitic composition. Near Slate Crag, 500 yds. west of Bowfell summit, Cumberland 408

Dates of Issue

VOLUME 65 (1954–5)

Part	1.	pp. 1–94	25 April 1954
,,	2.	pp. 95–202	25 June 1954
,,	3.	pp. 203–312	30 September 1954
,,	4.	pp. 313–432	17 June 1955

Proceedings of the
GEOLOGISTS' ASSOCIATION

The Geologists' Association and its Field Meetings

by G. W. HIMUS

Presidential Address delivered 5 March 1954

IN A little less than five years—on 17 December 1958 to be precise—our Association will have completed one hundred years of active life. The Centenary will doubtless be celebrated in traditional fashion, by the delivery of orations, the eating of dinners and other social gatherings. In addition to these ephemeral functions, it is the desire of the Council that there should be some permanent record of our Centenary, just as there was of the Jubilee of 1908. The suggestion is that there shall be two Centenary volumes published, one embodying a history of the first hundred years of the Association; the preparation of this volume is in the capable hands of our old friend, Mr. G. S. Sweeting, for many years our Honorary Editor. The other volume is designed to make available to students, amateurs and others, that information which is often so difficult to obtain, namely, how to make the best use of a few days in districts of geological interest and to be sure that, at the end of the time, the most important and interesting sections have been examined. The difficult task of preparing this volume has been undertaken by Dr. Vernon Wilson of the Geological Survey.

The subject of Field Meetings will be by no means the least important topic to be discussed in the proposed History, and, being 'under contract' to Mr. Sweeting to prepare a draft chapter on the subject, I propose to lay before you this evening some of the notes I have made.

In the original memorandum of the objects of the Association circulated in 1858 by the Provisional Committee, no specific mention is made of Field Meetings; nevertheless, in his Presidential Address, delivered on 5 November 1880, Professor T. Rupert Jones, in reviewing the objects of the Association, includes 'Field Lectures or Excursions'. He remarks:

> The founders . . . contemplated the cultivation of Geological Knowledge among the members by means of *mutual help*, variously given and received, under the following heads:
>
> I. Periodical meetings: Having in view
>   1. Reading and discussing Papers communicated by the Members.

2. Exhibition of Specimens with a view to (a) introducing new Fossils, Minerals, Rocks, etc.; (b) obtaining or rectifying Names.
3. Exchange of Specimens among the Members.
4. Giving and receiving Information as to (a) the Best Localities for Fossils, (b) the Best Methods of search and collection.
5. Dissemination of Geological Knowledge by printed Proceedings, separate Memoirs, and Notice papers.

II. A Library of Reference.
III. A Museum of Typical Fossils.
IV. Field Lectures or Excursions.
V. Courses of Lectures.
VI. Local Committees.

It is interesting to observe the stress which is apparently laid on the collecting and labelling of specimens, and the ambitious project of forming a 'Museum of Typical Fossils'. Even in the sixties and seventies of the last century, to acquire the premises and cabinets necessary to house such a collection would have taxed the ingenuity of an association boasting less than four hundred members, with an annual subscription of ten shillings. It is worth noting that in Category I, 4 (b), the 'Best Methods of search and collection' of fossils, there is in Vol. I of our PROCEEDINGS, the report of a paper by S. Highley on 'Geological and Mineralogical Hammers', a subject which one can scarcely imagine being brought before a meeting at the present day.

The keynote to the activities of the Association was sounded by the first President, Toulmin Smith, in an address delivered in January 1859, on 'The Finding of True Facts', in which it is stressed that the object of the Association as a corporate body should be to accumulate reliable geological information by careful and accurate observation in the field. That the admonition was taken to heart and acted on is shown by the records in our PROCEEDINGS. Among the outstanding investigations may be mentioned the zoning of the Chalk of the English coast by A. W. Rowe and C. D. Sherborn in the early years of the present century, followed by similar work inland, by G. E. Dibley, G. W. Young, A. J. Bull and C. T. Gaster, to mention only a few names. Still later, a concerted attack was made with the object of constructing a geological map on the six-inch scale of the Weald by a Committee under the chairmanship of the late Dr. A. J. Bull. Although this project is unfinished and is never likely to be completed, the forty-two published papers by various members of the Committee are sufficient evidence of its activities.

But while the primary object of a geologist must be the collection of facts, unless and until those facts have been checked and communicated to others, they cannot be considered to form part of or to contribute to the progress of our science. And how can observations best be communicated to others better than by direct demonstration in the field?

Field Meetings, or 'Excursions' as they were then called, started on quite a small scale in 1860. Three visits were paid, (i) to Folkestone, on 9 April, (ii) to Maidstone, on 19 June, and (iii) to Charlton, on 13 August. We are informed that the party visiting Folkestone travelled from London on an excursion train which departed at 8.35 a.m. and arrived at its destination 'soon after twelve o'clock'. To judge from the rather meagre report, some special arrangement or concession was made by the directors of the railway company for the benefit of the Association, but no details are available. The main object of the excursion to Maidstone was to inspect the quarry in Hythe Beds from which was derived the type specimen of *Iguanodon mantelli*, in 1834. Nearly a fortnight later, on 2 July, W. H. Bensted, one of the Directors of the excursion and the owner of the quarry in question, read a paper 'On the Kentish Ragstone as exhibited in the Iguanodon Quarry at Maidstone'. This is reported in Volume I of the PROCEEDINGS and, in the copy housed in the library of the Geological Society, there is bound in with it a somewhat faded stereoscopic photograph showing part of the working face of the famous quarry.

In the Annual Report for 1860, we read that 'a series of excursions to places of Geological interest was commenced—Folkestone, Maidstone and Charlton being visited. As these excursions gave great satisfaction to the members, it is intended to follow the same course, and to again hold two or three field lectures before the close of the present session. . . .' Reading between the lines of the report, one gathers that the General Committee must have heaved a sigh of relief when they found that their rather daring innovation of organising excursions had proved a success. It is on record that, at one time, doubt was expressed whether ladies could be expected to participate in the rigours of geological excursions, and a suggestion was made, though apparently never carried out, that special excursions might be organised for the benefit of the so-called 'weaker sex'.

For the next ten years, the programme of excursions remained modest, no more than five Field Meetings being held in any one year. In 1863, however, an important precedent was set, for it was in this year that the first 'long' excursion, lasting two days, 27–28 May, was carried out, when a party attended the Anniversary Meeting of the Dudley Geological Society, by invitation. The report on this excursion was read to the members of the Association at the Ordinary Meeting on 6 July 1863. This reading of reports of excursions at meetings seems to have been a normal practice in those days. In the same year (1863) a visit was paid to Dover on 20 August, and is the subject of a long report in the *Colliery Guardian*, which starts with a highly eulogistic tribute to the then President, J. Tennant. Appended to the report is a disquisition by S. J. Mackie, entitled 'Thoughts on Dover Cliffs', in which the author gives vent to some decidedly catastrophic doctrines concerning the elevation of the Weald and the irruption of the sea to form the Straits of Dover.

Although the earliest excursion lasting more than one day was made in 1863, it was not until 1870 that the experiment of a two-day meeting was repeated. In this year, at Whitsun, on 9–10 May, Stroud and May Hill were visited, and the excursion was extended to a third day, which was devoted to visits to Swindon and Faringdon. Since 1870, excursions of two days or more have taken place at Easter and Whitsun, and in the summer, 'long' excursions, lasting from as little as two days to as much as a fortnight, have been the regular practice except during the war periods.

The year 1878 is important, since it was then that the first of many visits was made to the Continent, the long excursion in the summer being to the Boulonnais. In preparation for the excursion, a paper entitled 'A Geological Sketch of the Boulonnais' was presented at the ordinary meeting on 5 July; it gives a very complete account of the ground which was covered a month later, from 5–10 August inclusive. The report on the excursion makes interesting reading. We are informed that the party arrived at Boulogne at 3.40 p.m. and was subsequently welcomed by the Mayor of Boulogne, who 'invited the Members to a lunch'. Whether the lunch took place we know not. No further mention is made of it in the report. During the excursion 'Mr. J. Grant, a Member of the Association, found a very interesting fossil in the Blacourt Limestone—*Spirifer Orbelianus* (Abich)—as that form was only hitherto known in Ardennes and in Russia'. This is probably the earliest record of a discovery having been made by a member during a Field Meeting. It was during this excursion that the graceful precedent was established that, on the last evening of a foreign meeting, the Directors should be entertained to dinner by the party.

It was not until August 1885, that another continental excursion was carried out; on this occasion, the scene was Belgium and the French Ardennes. Again, the areas to be visited were described by Professors J. Gosselet and T. G. Bonney, in the form of an advance pamphlet (consisting of viii+59 pp., with 3 maps and 14 cuts). The papers were not read and are, unfortunately, not published in the PROCEEDINGS. In his introduction to the report on the meeting, the President, W. Topley, says: 'The ordinary excursions of the Association are necessarily confined mainly to the immediate neighbourhood of London. At Easter or Whitsuntide it is possible to visit the outlying Cretaceous or Jurassic areas; but it is only during the Long Excursion that we can make acquaintance with the older rocks.' This was a rather pessimistic view, for on several occasions before 1885, Palaeozoic and Pre-Cambrian rocks had been examined during two-day excursions.

In 1879, effect was given to Object V of the Association in that a series of five excursions, called the 'Weald Series', was organised. These comprised visits to (1) Orpington and Knockholt, (2) Knockholt and Sevenoaks, (3) Sevenoaks and Tonbridge, (4) Tonbridge and Tunbridge Wells, and (5) Tunbridge Wells and Crowborough Beacon, all of which were directed by J. Logan Lobley, so that 'those Members who are unable to go far afield were thus afforded an excellent opportunity for studying the physiography of that remarkable region which forms the southern curve of the London Basin in the western part of Kent'. Forty-five years later, an organised attack on the geology of the Weald was initiated, and various aspects of wealden geology have been the subjects of many Field Meetings during the last thirty years.

Until 1886, there was no Secretary for Field Meetings; the General Secretary was charged with the duties of arranging not only the programme of indoor meetings, but also of excursions and visits. At the Annual General Meeting, on 4 February 1887, an additional Secretary, in the person of Mr. B. B. Woodward, was appointed to carry on the ordinary business of the Association, while the existing Secretary, Dr. J. Foulerton, without any special title, relinquished the more general duties and specialised in the organisation of excursions and visits. No special title appears to have been attached to this secretarial position, however, for it is not until the Annual Report for 1911–12 that an 'Excursion Secretary' is separately mentioned in the 'House List'. There does not seem to have been a Committee especially charged with the duty of helping the Excursions Secretary. The first mention of a special Excursions Committee is in the report for 1913, where it is stated that such a committee was appointed in March 1913.

Our first and, to date, only visit to Italy was made in 1889, when there was a tour in the volcanic regions of Italy under the direction of Dr. Johnston Lavis, a member of the Association. This was something like an excursion, for it lasted for about six weeks. The latter half of September was devoted to Sicily and the Lipari Islands, and the whole of October to the districts around and between Naples and Rome. Strangely enough, this, our longest excursion, does not figure in the 'Chronological List of the Longer Excursions' given in the Index to Vols. I to XX of the PROCEEDINGS, nor is it mentioned in Professor Watts's tabulated summary of excursions and visits in the Presidential Address in 1909. In Holmes & Sherborn's 'Record of Excursions', it is stated that the Italian tour was 'in addition to the ordinary programme for the year'. One wonders whether this apparent tendency to play down what still remains our record Field Meeting was due to uneasy twinges of the Victorian conscience at the idea of having spent six weeks holiday-making instead of the conventional fortnight.

Prior to our Jubilee in 1908, six visits had been paid to the Continent, all to France and Belgium. Among the high lights of an excursion to the Auvergne, in 1901, was a chance meeting with Michel Levy, 'who in his specially designed surveying motor car was continuing those researches which have done so much to elucidate the geology and former history of Mont Dore'. This must surely be one of the earliest applications of the automobile to geological surveying, if not the first. The record tantalisingly omits to give any details of the equipment of the vehicle.

Until the outbreak of war in 1914, there was only one more foreign excursion, namely to Bergen, in 1911. A projected visit to the Eifel in the summer of 1914 was perforce abandoned, but in a modified form was carried out twenty-three years later, in 1937.

The war had less effect on the outdoor activities of the Association than might have been expected, for it was not until 1917 that long excursions were suspended, and, in that year, Saturday excursions were limited to two a month. Even so, eight half-day and two whole-day meetings were successfully carried out. Even in 1918, there were a number of excursions, only half-day, it is true, but eight were successfully carried through.

With the cessation of hostilities, outdoor activities were immediately resumed and, in 1919, a full programme was accomplished.

The outbreak of war in 1939 caused an immediate cessation of all activities of the Association; the normal monthly meetings were, however, resumed early in 1940 and thereafter continued without a break. A somewhat curtailed programme of Field Meetings was planned for 1940 and partially carried out. In particular, we may mention a long week-end at Bath at Easter. This was commemorative of the centenary of the death of William Smith, in 1839. The meeting had been planned to take place in the autumn of 1939, but suffered the fate of other fixtures. At Whitsun, a four-day meeting was held at Lincoln, but by now the war had flared up; Holland and Belgium were invaded and, by the middle of June, France had capitulated, and it was expected that England would be invaded at any moment. All preliminary arrangements and plans for further Field Meetings perforce went by the board and, for the ensuing three years, no attempt was made to revive outdoor meetings.

Towards the end of 1943 suggestions were put forward that Field Meetings might be restarted. A new committee was appointed, and a skeleton programme was arranged. Conditions were by no means easy; local transport was not available; railway facilities were greatly restricted, and, from the middle of June until well into August, London and the south-east of England were subjected to heavy and nearly continuous attack from flying bombs. In the report of a meeting at Elmstead Woods, Kent, Mr. Wrigley notes that 'the Director had to interrupt his discourse while overhead a flying bomb snorted Londonwards'. The long meeting, which was held at Dolgelly towards the end of August, was memorable to the

London contingent particularly, not only for the geological interest of the district, but, perhaps, even more so, because it was possible to go to bed undressed, in the confident assurance that there would be no alarms and excursions during the night.

In 1946, the only approach to a long Field Meeting consisted in a two-day visit to Wellington in the autumn. There were, however, fourteen day and half-day meetings.

The cessation of hostilities in 1945 was accompanied by little easing of the situation as far as Field Meetings were concerned. Transport was difficult to arrange and expensive; accommodation was scanty and, as a result, at Easter, 1946, a successful experiment was carried out, when G. S. Sweeting led a four-day meeting at Ashover, in Derbyshire, the participants being accommodated by twos and threes in cottages. Although the sanitary arrangements were sometimes a little primitive, there were no complaints—there were no complaints of any shortage of food or of bad cooking! In 1946, we were able to run two simultaneous Field Meetings at Whitsun, to Kettering and in the Weald respectively, while there was an early summer meeting to Snowdonia at the beginning of July, lasting a week.

The first post-war overseas meeting was held in 1947, when Professor J. Cadisch, ably assisted by a number of his colleagues, conducted a party on a traverse of the Alps, from Bern to Zurich, fourteen days being spent in the field. This meeting provided a wonderful example of first-class organisation. Preliminary discussions between Professor Cadisch and Mr. Emil Montag led to the conclusion that fr. Swiss 400 would be an adequate sum to charge each participator in the meeting. On arrival at Bern, all travellers' cheques were collected and handed to Professor Cadisch, who arranged that they should be cashed; the necessary payment was collected, and the balance in cash was returned to each member. Thereafter, we all knew how much spending money we had; there were no further demands, and all payments were made on our behalf by the Swiss secretary to the meeting, who, when required, played the part of interpreter. Quite apart from the geological interest of the meeting, the change from the austerity of wartime and post-war Britain to the relative luxury of Switzerland rendered the visit memorable to all who took part.

In spite of restrictions on the taking of currency out of Great Britain and other difficulties, there have already been three foreign meetings since 1945; in addition to the Swiss meeting in 1947, Norway was visited in 1950, and the Central Massif of France in 1951. A meeting was projected n Portugal in 1949, but came to nought owing to lack of support. But, in September this year, it is proposed to visit Italy.

Since those far-off days of the first excursion to Folkestone, parties of our members have studied the whole range of geological formations, from the

Pre-Cambrian to the Recent. Nearly every area of geological interest in England and Wales has been visited; Scotland and Ireland have been only partially covered. Our twenty visits to Europe have never taken us north of Bergen or east of Prague. Sweden, Denmark, the Iberian Peninsula, the interior of Germany, Russia, Austria and the Balkans have not yet been investigated by our field-parties, while the world outside Europe is still *terra incognita*, although it may be expected that before many years have passed, advantage will be taken of the speed of aerial travel and field parties will be found at work in Africa, Asia and the New World.

As one would expect, a considerable mass of literature dealing with Field Meetings has grown up. With a few exceptions, notably the meetings in Czecho-Slovakia, in 1925, and in the Departments of Maine et Loire, in 1928, there are in the PROCEEDINGS more or less detailed reports which provide valuable guides for those who would visit the ground traversed by previous field-parties. The reports, while generally adequate on the geological side, tend to be somewhat inhuman; no one, reading the staid and factual accounts would suspect that geologists could ever be guilty of 'letting their hair down'. As is truly stated, in the report of the Swiss meeting of 1947, on Sunday, 7 September, 'a lunch was provided at Guggisberg'. No mention is made of the high light of the occasion, namely, that between courses, the party was regaled with a concert by Professor R. F. Rutsch on the concertina and Dr. K. Arbenz on the double bass, with songs by a bevy of the local beauties clad in their cantonal costumes, yet this was an outstanding feature of the meeting.

Information on where to stay, and particularly on what places to avoid, would be of value. Many of us must have vivid recollections of hotels which, while providing good accommodation for two or three, proved quite unsuitable when asked to deal with a party of thirty.

Numerous Field Meetings have been prefaced by the issue of preliminary accounts of the ground to be covered, which were subsequently published in the PROCEEDINGS; these are always worth picking up at a second-hand bookshop. Could such preprints be issued more frequently, the benefit to members would be great.

Although they are often regarded as ephemeral publications and quickly discarded, the Monthly Circulars are a fruitful source of information when planning a field trip. Not only do they suggest programmes which can be carried out in a day or a half day, but the appropriate sheets of both geological and topographical maps are generally given, together with references to previous work on the areas considered. In some of the older circulars, there are sketch-maps and sections, but the practice of introducing these has fallen out of use, partly, presumably, on account of the high cost of reproduction.

The Association owes much to the Directors of its Field Meetings, both amateur and professional. While many day and half-day meetings have been directed by amateurs, the Directors of the longer meetings have almost always been provided either by members of the Universities or of the Geological Survey. These have given up from a week to a fortnight of their summer leave, at their own expense, to the difficult task of conducting the heterogeneous collections of individuals who constitute a Geologists' Association field-party. To be a successful Director demands not only an intimate knowledge of the ground to be covered, but a flair for imparting geological information in such a form that it will be acceptable not only to the member who is well versed in geological lore, but also to the tyro who has barely touched the fringe of the subject. That our Directors meet with such uniform success is clear evidence that the pursuit of geology does not have, as some seem to imagine, a dehumanising effect, but quite the contrary.

Less conspicuous, but equally necessary to the success of a Field Meeting, is the Secretary who undertakes the arduous and rather thankless duty of organising transport and accommodation and who is, in fact, the administrator. Just how much bother is saved to the individual by the backstage work of the Secretary is not always appreciated. Often, it is only the Director and the President, or his representative, on a meeting who fully realises how much the unfortunate Secretary has had to put up with.

Our records do not indicate that there has been any long-range planning in the arrangement of Field Meetings; it is true that there is an endeavour to provide variety from year to year, but in the last analysis, everything turns on the availability of Directors. The five excursions comprising the 'Weald Series' in 1879, and eight excursions in 1919, arranged specially to study the gravels of the Thames Basin under the auspices of the 'recently formed', and short-lived, 'gravels committee' are examples of planned series of Field Meetings, while members of the Weald Research Committee have for many years demonstrated the results of their work on a large number of occasions.

Members of Council and the Field Meetings Committee are usually well enough informed about the progress of the major geological investigations, and they have no hesitation in asking the investigators to demonstrate the results of their work, and favourable replies are generally forthcoming. There must, however, be a considerable amount of untouched talent. Quite a number of members are probably carrying out local and ntensive studies on one problem or another, the results of which should be put on record and which would provide interesting demonstrations in the field. It is not out of place to appeal to such members to take thought whether they should not share their discoveries, trifling though these may appear to be, by offering to lead day or half-day meetings.

Although the Association originated in London, an increasing proportion of our members, probably at least half, live in the Provinces and are unable to attend regularly meetings in or around London. To overcome this difficulty, local Groups have been formed by enthusiasts in Lancashire, Birmingham and Staffordshire. In addition to meetings for lectures and discussion, the Groups run Field Meetings in their own districts which are well attended and which, in any statistical survey, should be included with those organised by the Field Meeting Committee. Even during the war, several Field Meetings were run each year; it is therefore not strictly correct to say that from 1942 to 1944 there were *no* Field Meetings.

Our record as a body, which encourages and promotes original geological research and its demonstration in the field, is a proud one. Enough has been said to prove that, in fair weather and in foul, we have carried on the principal task set us by our founders; may this happy state of affairs continue!

And now, my task as your President is ended. It remains for me to thank you, Members of the Association, for honouring me by electing me to the Chair for two successive years. I must also express my gratitude to the Members of Council for their continued support in what has been a labour of love, before I vacate the Chair in favour of Dr. L. R. Cox, who is well known to you. I can only wish that his term as President may be as pleasant and peaceful as mine has been.

The Silurian Rocks of Kendal End, Near Barnt Green, Worcestershire

by W. G. HARDIE

Received 28 August 1952

CONTENTS

INTRODUCTION ... ... page 11
DESCRIPTION OF THE AREA 12
AGE OF THE BEDS 14
ACKNOWLEDGMENTS 17
REFERENCES 17

UMMARY. The Silurian rocks of Kendal End occupy a small fault-bounded iangular area, surrounded on all sides by the Pre-Cambrian Barnt Green rocks. ew exposures are now visible, and the fossils mentioned in the text were obtained om a trench dug in one of the old quarries. A study of the specimens of *Atrypa* con-rms Lapworth's view that the beds are equivalent to the Woolhope Limestone in ge.

---

1. INTRODUCTION

HE EXISTENCE OF a small area of Silurian rocks, immediately south of the ickey Hills (Fig. 1), has been known for over a century, but little has been ritten about it. Although the rocks were formerly quarried for lime, the uarries have long been completely overgrown, and can now only be vestigated by trenching and augering. The area falls within Sheet 54 NW. Old Edition) of the one-inch Geological Survey map, of which there is o descriptive memoir.

According to Murchison (1839, p. 439), who first recognised the Wen-ck age of the beds, the quarrying operations exposed a steeply dipping ed of limestone about five yards thick, together with shale-containing mestone nodules. Towards the end of the century, however, the quarries ere completely overgrown and consequently Lapworth (1898, p. 358–9) ould only find fragments of fossiliferous limestone in the shale of the uarry-waste. Without recording the fauna, he stated that the beds were uivalent to the Woolhope Limestone. It is not clear, however, whether is correlation was based upon the faunal content of the rocks or simply pon the lithological similarity of them to certain limestones near Rubery, the northern end of the Lickey Hills, which are also correlated with the oolhope Limestone

2. DESCRIPTION OF THE AREA

Although the Wenlock rocks give rise to a light grey soil, which contrasts with the purple-brown soil derived from the surrounding Pre-Cambrian, for various reasons the junction between the two rock-groups is not everywhere clearly defined. Therefore, in order to overcome these uncertainties as far as possible, the mapping of the area was carried out with the aid of a number of shallow auger-holes. The result of the mapping (Fig. 2) has been to show that the area of Wenlock rocks is smaller than is shown on the unpublished maps in the Department of Geology at Birmingham University, while the area is probably surrounded by three faults and not four as hitherto believed.

Three other points worth noting in connection with the mapping are as follows: (1) the greater part of the western junction of the Silurian south of the farm road is covered by a foot or more of boulder clay; (2) the southern part of the eastern junction can be accurately located on account of the contrasted colour of the soil on either side of it; (3) the sloping banks of the old quarry north of the farm road consist of weathered Pre-Cambrian material (mainly fine tuff), and this suggests that the Silurian was quarried up to the limits of its outcrop at this locality. Blocks of limestone can be found over much of the quarry-floor under a cover of water-logged soil, but in the northern part of the quarry only a tenaceous red clay appears to be present. This clay, which is regarded as soil-wash largely brought in by a small seasonal stream draining the ground to the north, has only been penetrated by auger-holes to a depth of two or three feet, but there seems little doubt that it is underlain by Silurian at no great depth.

In the hope of exposing the rocks *in situ* and of collecting fossils, two trenches were dug in the old quarry immediately south of the farm road (Fig. 2). One of these exposed greyish coloured shales together with a slightly nodular bed of limestone approximately four inches thick. The beds were seen to have a steep westerly dip, but it was uncertain whether or not their attitude was due to slipping subsequent to quarrying. The limestone was frequently veined with calcite, and locally contained small amounts of galena. With the exception of *Bilobites* sp. found in the shale, the rocks were unfossiliferous. The other trench unfortunately only exposed quarry-waste, but this proved to be highly fossiliferous. The fossils obtained are given in the following section of this paper.

It might be added that no confirmation has been obtained of the presence of fragments of Rubery Sandstone (Upper Llandovery), which, according to Lapworth (1898, p. 358), occur near the southern extremity of the area.

A short distance west of the area just described, at the locality marked X in Fig. 1, a very much smaller outcrop of fossiliferous Wenlock Limestone has recently been exposed in two drainage trenches. One of these

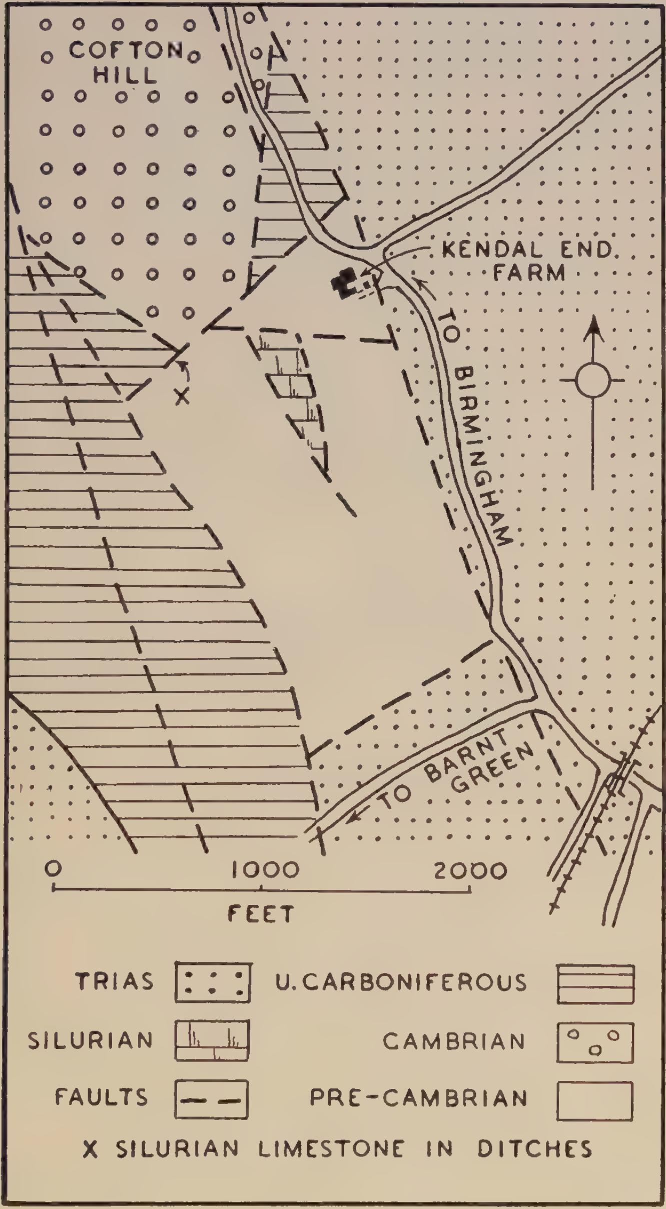


Fig. 1. Geological map of the Kendal End district

trenches runs along the northern side of a field belonging to Kendal End Farm, while the other trench lies in the wood a few yards farther north. Although the exact limits of the limestone cannot be determined, it seems probable that the limestone forms a wedge-shaped outcrop caught up in the fault between the Pre-Cambrian and Upper Carboniferous rocks. These latter rocks are exposed in the western part of the drainage-trench in the farm property, where they are overlain by a thin cover of boulder clay, and are seen to consist of strongly coloured blue-grey non-calcareous silty clays (? Halesowen Beds). They thus differ both in colour and in silt-content from the adjacent Wenlock rocks of the main outcrop. Similar silty clays, sometimes overlain by boulder clay, have been proved in the woods to the north of the trench by putting down shallow auger-holes. Westwards these beds give way to typical Keele Beds, characterised by red clays locally containing thin beds of red sandstone.

A discussion on the age of the faulting affecting the Wenlock rocks lies outside the scope of this paper. Suffice it to say, however, that some of the faulting, like that affecting the eastern side of the Lickey Hills (Fig. 1; Wills, 1950, p. 79), may well be post-Triassic in age.

3. AGE OF THE BEDS

A trench was dug in the clay of the quarry-waste immediately south of the farm road (Fig. 2) for the purpose of collecting fossils, and the following fauna was obtained.

Anthozoa:	? *Cetophyllum duplex* (Butler)
	Cymatelasma sp.
	Favosites gothlandicus (Lam.)
	Syringaxon siluriensis (McCoy)
Brachiopoda:	*Atrypa reticularis* (Linn.)
	Barrandella linguifer (J. de C. Sow.)
	Bilobites sp.
	Dolerorthis rustica (J. de C. Sow.)
	Leptaena rhomboidalis (Wilck.)
	Orbiculoidea forbesi (Dav.)
	Parmorthis sp.
	Rhipidomella hybrida (J. de C. Sow.)
	Plectodonta cf. *transversalis* (Wahl.)
	Streptis grayi (Dav.)
	Cryptothyrella cf. *angustifrons* (McCoy)
Gastropoda:	*Poleumita* sp.
Cephalopoda:	*Dawsonoceras annulatum* (Sow.)
Trilobita:	*Calymene blumenbachi* (Brongn.)
Echinodermata:	Crinoid ossicles.

The collection is deposited in the Department of Geology, Birmingham University (Reg. Nos. B.U. 609–B.U. 640).

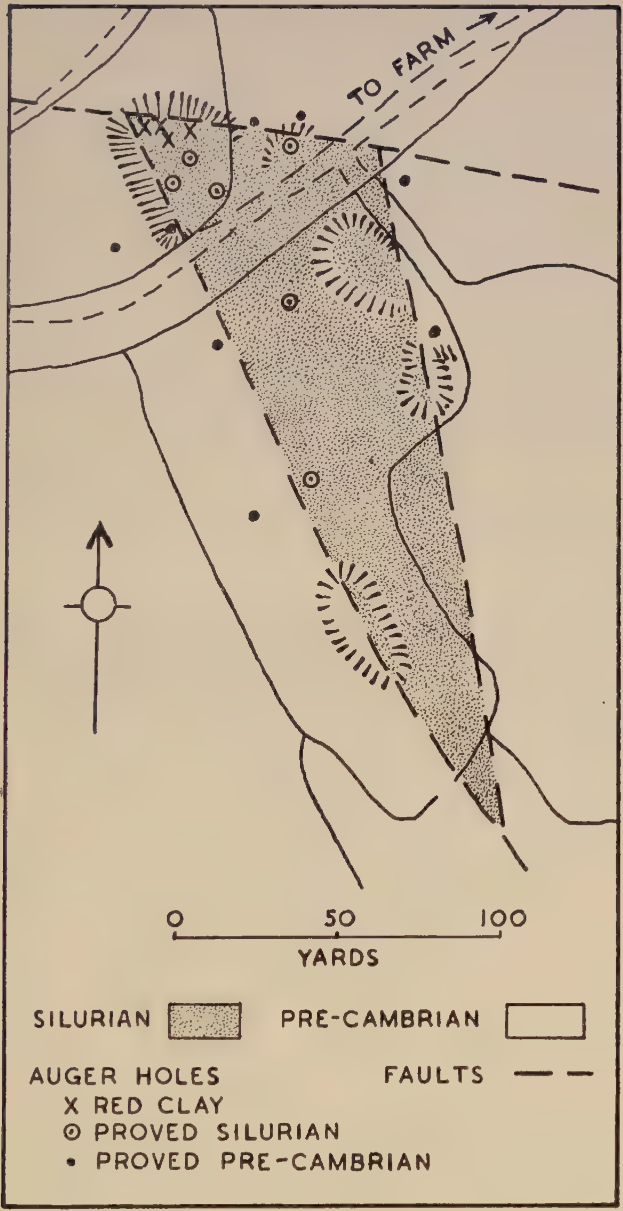


Fig. 2. Map showing position of auger holes

In this typically Wenlockian assemblage, *Atrypa reticularis* is by far the most common fossil, followed by *Plectodonta*.

The ten specimens of *Atrypa reticularis* were measured and otherwise examined according to the procedure given by Alexander (1948), and the results are given in Table I below. In this table the last column, headed 'shape of shell', shows how each specimen compares with the photographs of the specimens, shown in Mrs. Alexander's paper (1948, pl. X). Thus, for instance, 'Woolhope–Wenlock type' signifies that the specimen is intermediate in shape between the type specimens from these two horizons. In a few cases the preservation of the shell did not permit measurements being made.

TABLE I: **Analysis of specimens of *Atrypa reticularis* from Kendal End.**

Specimen No.	Length (mm.)	Breadth (mm.)	Depth (mm.)	No. of ribs per 5 mm.	Shape of shell
B.U. 613	16.5	16.8	9.4	4 to 5	Woolhope type
B.U. 614	18.1	18.6	11.0	4 to 5	Woolhope–Wenlock type
B.U. 615	18.5	—	9.7	—	,, ,, ,,
B.U. 616	19.8	17.9	9.5	5	,, ,, ,,
B.U. 617	18.4	17.8	10.2	4 to 5	Woolhope type
B.U. 618	18.3	16.5	10.9	—	Woolhope–Wenlock type
B.U. 619	17.3	17.1	9.3	5	Woolhope type
B.U. 620	20.6	21.1	11.7	—	Wenlock Shale type
B.U. 621	20.3	18.6	10.7	4 to 5	Woolhope–Wenlock type
B.U. 622	20.2	24.0	9.3	4	Woolhope type
Average:	18.8	18.7	10.2		

Average figures given by Alexander (1948):

	Top of Llandovery and Woolhope Limestone specimens	Wenlock Shale specimens	Wenlock Limestone specimens
Length	about 18 mm.	17 mm.	18 mm.
Breadth	about 18 mm.	16 mm.	18 mm.
Depth	about 10 mm.	11 mm.	11 mm.
No. of ribs per 5 mm.	4	5 or 6	5 to 7

Comparison of the results shown in Table I with the average figures for *Atrypa reticularis* from three different horizons, as given by Mrs. Alexander, strongly suggest that the Kendal End Beds are equivalent to the Woolhope Limestone in age. With one exception, the shape of the shell also lends support to this conclusion.

These results are of interest, since they confirm Lapworth's views, already mentioned, about the age of the beds.

ACKNOWLEDGMENTS

The corals were kindly identified by Dr. Stanley Smith to whom the writer is accordingly grateful. To Professor L. J. Wills and Professor F. W. Shotton thanks are due for permission to use their unpublished six-inch map of the south end of the Lickey Hills, which appears in a slightly modified form in Fig. 1. Thanks are also due to Dr. Isles Strachan for helpful discussions during the course of the work.

REFERENCES

ALEXANDER, F. E. S. 1948. A revision of the brachiopod species *Anomia reticularis* Linnaeus genolectotype of *Atrypa* Dalman. *Quart. Journ. Geol. Soc. Lond.*, **104**, 218–20.

LAPWORTH, C. 1898. A sketch of the geology of the Birmingham District. *Proc. Geol. Assoc.*, **15**, 358–9.

MURCHISON, SIR R. I. 1839. 'Silurian System', Part I.

WILLS, L. J. 1950. The palaeogeography of the Midlands. 2nd ed., University Press, Liverpool.

Field Meeting in the Vale of St. Albans

Sunday, 13 September 1953

Report by the Director: P. EVANS

Received 4 November 1953

THE FIELD MEETING was arranged to enable members to examine the Pleistocene deposits near St. Albans, to get some idea of the topography of South Hertfordshire, to see a few of the swallow-holes and collapses near the Eocene–Cretaceous boundary, and to look at specimens of the Hertfordshire Puddingstone.

The party first visited Aldenham, where puddingstone has been extensively used in the buttresses of the church, and then walked from Letchmore Heath over an area with several collapses to Batlers Green (156.985), where buildings, incorporating several types of puddingstone, were inspected.

The gravel pit west of Moor Mill, Colney Street, is nearly worked out, but fresh sections were seen near the southern end (140.024) and partially obscured sections were still visible at the northern end (145.028). The pit has exposed a lower bed of gravel and sand up to 17 ft. thick overlain by laminated clay, 4 to 5 ft., which is followed by boulder clay, about 12 ft., capped by an upper gravel 13 ft. thick. The laminated clay in much of the pit is divisible into an upper half of alternating bands of laminated cream silty clay and dark-grey clay and a lower half of brown well-laminated clay. The dark-grey clay is similar to the matrix of some of the darker boulder clay of the neighbourhood, whilst the lower brown clays suggest derivation from Reading Bed material. In places material derived from the laminated clay is incorporated in the overlying boulder clay, and some of the laminated clays *in situ* show small-scale disturbances. Details of the sections are given in the appendix.

The Director referred to the common occurrence of moraine-dammed lakes near the edges of an ice-sheet and suggested that the laminated clays are lacustrine deposits laid down during a temporary retreat of the glacier, the banding being in most cases an indication of seasonal variations in deposition and thus comparable with the Swedish varves. The laminated clays extend for at least 600 yds. in the Moor Mill pit. A number of other occurrences of laminated beds in the district are mentioned in the *Survey Memoir* (Sherlock & Pocock, 1924).

After lunch the party travelled eastwards along the Vale of St. Albans.

From the coach the Director pointed out the main topographical features, including the abandoned meander of the Ver at Park Street (Wooldridge, 1953).

Many of the sections formerly visible in the St. Albans Sand and Gravel Co.'s pit at Smallford are no longer exposed, but a fresh section at the northern end of these workings (193.067) gave the following sequence:

Gravel and sand	17 ft.
Dark-grey boulder clay with numerous flints and smaller fragments of Chalk	13 ft.
Gravel and sand	17 ft.
Chalk	

In the nearby pits of Messrs. Inns & Co., south-east of Sleepshyde, the following section was seen in the present working face (204.067):

Gravel and sand, including near the base a lenticular grey sand with Foraminifera, etc.	11½ ft.
Cream, yellow, and brown sand	0 to 6 ft.
Grey very chalky boulder clay	0 to 1¼ ft.
Grey impure sand, from fine to very coarse	0 to 2 ft.
Banded clayey sand, light blue-grey	0 to 6 ft.
Dark-grey boulder clay, much Chalk and many small pebbles of vein quartz	8 ft.
Brown boulder clay	1½ ft.
Gravel with little sand	7 ft.+

The individual beds of the upper gravel and the beds between this gravel and the boulder clay show much lateral variation. The blue-grey banded clayey sand shows distinct colour-bands on a fresh surface; the banding is more clearly brought out as fine corrugations on a weathered surface.

Throughout the pits visited the boulder clay was seen to lie between two beds of gravel. The lower boulder clay resting directly on the Chalk was not found. In Moor Mill pit the laminated clay is below the boulder clay but in Sleepshyde pit the banded clayey sand is above the main boulder clay, although below a thin lenticular boulder clay.

Mr. S. Waller has obtained from a two-foot bed of grey sand in Sleepshyde pit a large number of well-preserved Foraminifera (Carboniferous, Jurassic and Cretaceous species, with arenaceous Lituolidae dominant) and some Ostracoda. He kindly passed round his slides for inspection and took members to the exposure which has yielded the micro-fossils. Mr. J. F. Wyley, who had also been working in the pit, showed a selection of fossils obtained from the weathered tip heaps, and led members in a brief search for specimens.

Near Bayford, a visit was paid to the old sand-pit (305.098) now used by Messrs. G. Skinner & Sons for their tar-macadam plant, to see a bed of cemented sand and gravel. This hard bed of sandstone and conglomerate, which occurs in the fluvio-glacial deposits, owes its character to a calcareous cement.

The party went on to Water End, North Mymms (231.043), so that the swallow-holes could be seen (Wooldridge & Kirkaldy, 1937; Kirkaldy, 1950), and later to South Mimms to visit the less well known swallow-holes and collapses in the valley of the Catharine Bourne (214.014).

The Director then drew attention to the broad horseshoe valley through Borehamwood and Mimms which seems likely to be an abandoned loop of the Thames when that river followed the course through the Vale of St. Albans first suggested by Dr. Sherlock (Wooldridge & Kirkaldy, 1937; Wooldridge, 1938). From near Stirling Corner the contrast between the low ground of the Brent tributaries, which are cutting back northwards, and the higher ground of the Borehamwood–Mimms loop was pointed out. The coach then took the party along the Pebble Gravel ridge of Elstree and so to Watling Street and back to Charing Cross.

Dr. Pocock thanked the Director for leading the field meeting and for preparing notes for the use of members attending. Mr. Evans, in replying, thanked Miss Burbidge for her efficient work as Secretary for the meeting and endorsed Dr. Pocock's tribute to the pioneer work of Dr. Sherlock, the value of which was not fully appreciated at the time.

REFERENCES

Evans, P. 1944. Field Meeting at Waterend, North Mimms, Hertfordshire. *Proc. Geol. Assoc.*, **55,** 189.

Kirkaldy, J. F. 1950. Solution of the Chalk in the Mimms Valley, Herts. *Proc. Geol. Assoc.*, **61,** 219.

Sherlock, R. L. 1924. The superficial deposits of South Buckinghamshire and South Herts. *Proc. Geol. Assoc.*, **35,** 1.

——— & R. W. Pocock. 1924. The geology of the country around Hertford. *Mem. Geol. Surv.*

Wooldridge, S. W. 1938. The glaciation of the London Basin. *Quart. Journ. Geol. Soc. Lond.*, **94,** 627.

———. 1953. Some marginal drainage features of the Chalky Boulder Clay Ice-Sheet in Hertfordshire. *Proc. Geol. Assoc.*, **64,** 208.

——— & J. F. Kirkaldy. 1937. The geology of the Mimms Valley. *Proc. Geol. Assoc.*, **48,** 307.

APPENDIX

Sections in Moor Mill Gravel Pit, near Colney Street

Sections measured in 1952 in the western face of the pit below a footpath may be summarised as follows. The northernmost section (700 yds. from the road between Moor Mill and Bricketwood) in which the varved clay was first noticed was:

Gravel with large and small broken flints and wisps of clay and sand	8 ft.+
Slightly contorted clay and sand	2 ft.
Laminated clay and silt, in places much disturbed	5 ft.

A section 60 yds. farther south showed boulder clay between the upper gravel and the disturbed laminated clays:

Sand and gravel	1 ft.+
Brown and red boulder clay	3¾ ft.
Yellow sand Black very sandy clay	¼ ft.
Disturbed beds, pockets of coarse and fine sand (with some flints) lying in a sandy grey clay; laminations broken by small 'faults'	3½ ft.
Clay, sandy in places, with a few flints and small lumps of Chalk; a few darker bands in the clay; indications of irregular bedding	6½ ft.
Gravel with sand, base not seen	16 ft.

Clay samples from this section were examined at Cambridge by Mr. R. West, working under Dr. Godwin's direction, but no pollen was found.

Sections 80–110 yds. farther south, gave the following sequence:

Gravel and sand		13 ft.
Darker clayey sand and gravel		1 ft.
Boulder clay	yellowish, sandy, 0 to 2 ft. dark brown 0 to 1½ ft. light to golden brown, 2½ to 4 ft. mole brown, 6 to 9 ft.	13 ft.
Laminated grey clay		4 to 5 ft.
Gravel and sand, base not seen		17 ft.

About 100 yds. farther south the laminated clay was divisible into grey clay above and brown below. This section was:

Gravel and sand	12 ft.
Purplish boulder clay	13 ft.
Grey laminated clay Brown laminated clay	3¾ ft.
Sand and gravel, base not seen.	

In a working face south-east of the last section, 100 yds. from the western edge of the pit, the section seen was:

Gravel all removed	--
Boulder clay	8½ ft.
Grey laminated clay Brown laminated clay	3½ ft.
Gravel and sand	12 ft.
Chalk with large flints	

Near this section there was seen a large mass of boulder clay replacing the whole thickness of the lower gravel and interfingering at the edges with wisps of sand.

The section at the south end of Moor Mill gravel pit, which was still being worked at the time of the field meeting, was seen to be as follows:

Upper gravel removed		—
Boulder clay, purplish grey, with a few small pebbles of chalk and flint		6 ft.+
Alternating bands of laminated cream silty clay and dark-grey clay	2¼ ft.	4¼ ft.
Well-laminated buff and brown silty clays	2 ft.	
Reddish-brown plastic clay		¼ ft.
Gravel with a sandy matrix		6 ft.
Chalk		

Field Meeting in the Caterham–Godstone District

Saturday, 11 October 1952

Report by the Director: R. BRADSHAW

Received 12 June 1953

TWENTY-SEVEN members and friends assembled at Caterham Station and thence walked by way of Harestone Valley Road to View Point. Although visibility was not good, it was possible to see from this point on the North Downs across the Gault vale to the ridge of Lower Greensand with Tilburstow Hill almost due south. Here, too, is the watershed between the head-waters of the Medway draining to the east and of the Mole draining to the west. The Director gave a brief outline of the day's programme.

From View Point the road leading westwards along the crest of the Downs was followed to the wireless station on Gravelly Hill where there are good exposures of disturbed Blackheath Beds, a gravel deposit with well-rounded flint pebbles, and clay-with-flints. There is often much intermixture of the two. Large spreads of these gravels were seen along the route from Gravelly Hill via War Coppice Road and the bridle road, west of Whitehill Tower, to Warwick Wold. Lower Chalk (*S. varians* Zone) was examined in the path leading down the scarp and Upper Greensand, which here makes a good shelf at the foot of the main scarp, in a road cutting north of Warwick Wold.

After lunch in Warwick Wold, the Pendell Court Sand Pit of Messrs. R. Barnard & Co. was then visited. Here a considerable thickness of current-bedded Folkestone Sands (foresets dipping to the south) is being worked. The top few feet are stained black and a very thin clayey band prevents this staining from percolating through the rest of the beds.

The party walked on, through Bletchingley, to the large pit of the Ham River Gravel Co. Ltd., in Hythe Beds. The main interest here is in the few feet of chert beds at the top of the Hythe succession protecting the current-bedded soft sands below and giving rise to the Lower Greensand escarpment.

The Hythe Beds were followed to the east as far as Tilburstow Hill where a member of the party, Mr. E. E. S. Brown, who had been a co-worker with the late Dr. A. J. Bull, gave a short introduction to the geology of the area. After a brief examination of the structure the party returned to Godstone for tea and dispersal.

The President, Dr. G. W. Himus, proposed a vote of thanks to the Director.

REFERENCES

GOSSLING, F. & A. J. BULL. 1948. The structure of Tilburstow Hill, Surrey. *Proc. Geol. Assoc.*, **59**, 131.

DINES, H. G. & F. H. EDMONDS. 1933. The geology of the country around Reigate and Dorking. *Mem. Geol. Surv.*

The Genus *Gibbirhynchia* in the British Domerian

by D. V. AGER

Received 9 July 1953

CONTENTS

1. INTRODUCTION ... page 25
2. STRATIGRAPHY ... 25
3. SYSTEMATIC DESCRIPTIONS ... 28
ACKNOWLEDGMENTS ... 50
EXPLANATION OF PLATE ... 50
REFERENCES ... 50

ABSTRACT: Seven rhynchonellid species from the British Middle Lias are referred to S. S. Buckman's genus *Gibbirhynchia*; of these, two are transferred from the genus *Tetrarhynchia* and three are new species. The genus and seven species are all re-described with details of internal structures not previously studied. They are shown to be of great stratigraphical value in beds usually lacking in ammonites. The evolution and geographical distribution of the species are also discussed.

---

1. INTRODUCTION

THE REMARKABLE lateral variation of the rhynchonelloid and terebratuloid faunas is one of the chief features of interest emerging from a revision of the British Domerian (Middle Liassic) Brachiopoda. It has, therefore, been essential to find some method of detailed correlation, particularly for the upper beds of the Domerian which are usually lacking in ammonites. Only one of the numerous brachiopod genera present appears to be sufficiently well distributed in both space and time to be of major stratigraphical value. This comprises a series of small, rather globose rhynchonellids which are here included in an emended version of Buckman's genus *Gibbirhynchia.*

All the species were greatly in need of revision, particularly with regard to their internal structures. These have been studied by the burning technique described by Buckman (1918), and by the serial grinding technique of Muir-Wood (1934 and 1936).

2. STRATIGRAPHY

The most recently expressed opinion on the ammonite zoning of the Middle Lias is that of Spath (1942) who recognises two major divisions. These are the zones of *Pleuroceras spinatum* and *Amaltheus margaritatus*, which are here termed the Upper and Lower Domerian respectively. The sub-zones given by Spath have not as yet been applied in Britain. The numerous finer divisions proposed by Buckman (1925) were largely hypothetical, and in most cases have never been confirmed by field evidence.

The best and most complete section in which *Gibbirhynchia* occurs is that of the cliffs on the Dorset coast, between Seatown and Eype Mouth. The lowest beds are only exposed west of Seatown, in the cliffs of Golden Cap. The general section here is as follows:

Toarcian		Down Cliff Clay
		Junction Bed
Domerian (=Upper Pliensbachian)	Upper	Thorncombe Sands (with the '*thorncombiensis* Bed' near the top) about 70 ft. thick
	Lower	Down Cliff Sands (with the '*margaritatus* Bed' at the top) about 75 ft. thick Micaceous Beds (with the 'Starfish Bed' at the top, the 'Eype Nodule Bed' about 60 ft. from the top and the 'Three Tiers' at the base) about 160 ft. thick
Carixian (=Lower Pliensbachian)		Green Ammonite Beds

Various fine sub-divisions of the Junction Bed have been recognised by Day (1863), Buckman & Jackson (1922) and Jackson (1926), but only the lowest few inches are referable to the Domerian. This is the 'Marlstone' layer which becomes much thicker inland. Owing to confusion over the use of this name, however, the recent Geological Survey Memoir on the Liassic ironstones (Whitehead *et alia*, 1952) recommends the use of the term 'Marlstone Rock-bed' for the hard beds in the upper part of the Middle Lias succession. That practice is here adopted.

The stratigraphical records inland are generally much more inexact than those of the coast. The Middle Lias may be summarised as comprising an ironstone or ferruginous limestone above (the Marlstone Rock-bed) and a varied series of sands, marls and clays below. Such a section is all that is usually recorded in the literature and on museum labels for the main part of the Middle Lias outcrop from Somerset to the Humber. As a result, it is impossible to ascertain the exact or even the relative stratigraphical horizons of the majority of museum specimens. Personal collecting has provided a great deal of information on this matter, but unfortunately many of the classic sections are now completely obscured. The rather different Yorkshire succession is not considered here because no specimen of *Gibbirhynchia* has yet been seen from that area.

In the Midlands area the Marlstone Rock-bed changes into an important ironstone, with corresponding changes in the brachiopod fauna. In the Survey memoir mentioned above, a two-fold division of the Rock-bed is recognised in certain areas—the 'Ironstone' above, and the 'Sandrock' below. These divisions, however, are only locally applicable, and *Gibbirhynchia* has not yet been recorded in the Sandrock.

A thin 'Transition Bed' has been recognised in many of the Midlands ironstone workings, welded to the top of the Rock-bed. It contains a distinctive fauna thought to be transitional between the Domerian and Toarcian, and is characterised particularly by the ammonite *Tiltoniceras acutum* (Tate).

The stratigraphical distribution of the seven species of *Gibbirhynchia* is shown below (Fig. 2). Two of these, *G. northamptonensis* (Davidson) and *G. gibbosa* Buckman, characterise the upper part of the Marlstone Rock-bed, and another, *G. micra* sp. nov. (p. 38), characterises the lower part. Thus a sub-division can be recognised in a bed which was previously thought to be faunally homogenous. The 'Transition Bed' of the Midlands contains a fourth species, *G. tiltonensis* sp. nov. (p. 46), which enables the bed to be recognised even when the characteristic ammonite is absent. It also enables the 'Transition Bed' to be provisionally correlated with a layer of the Junction Bed on the Dorset coast. This is the 'At' layer of Jackson (1926), which he doubtfully assigned to Buckman's *athleticum* hemera of his 'Harpoceratan Age'.

An interesting example of the use of the earlier species of *Gibbirhynchia* as stratigraphical markers is provided by the material obtained from the borings and shafts of the Kent coalfield, preserved in the Geological Survey Museum. A re-examination by the author of the specimens previously attributed to '*Rhynchonella*' *tetrahedra* (J. Sowerby) and '*Rhynchonella*' *northamptonensis* Davidson, indicated that they were actually referable to *Gibbirhynchia muir-woodae* sp. nov. (p. 40) and *Gibbirhynchia* cf. *amalthei* (Quenstedt). Since these species are now known to be characteristic of the *margaritatus* Zone, it may be inferred that only the lower part of the Middle Lias is present under Kent. Thus, in the Elham boring described by Lamplugh, Kitchin & Pringle (1923), the 'hard grey limestone' at the top of the Middle Lias was found to contain *G. muir-woodae*, whilst the overlying 'greenish-grey sandy limestone' contained a *Gibbirhynchia* close to *G. amalthei*. A similar distribution occurred in all the other cores examined, suggesting a wide-spread break at this level, due presumably to post-Domerian erosion in the vicinity of the London–Ardennes ridge. No ammonites have been found in the Middle Lias of these boreholes.

3. SYSTEMATIC DESCRIPTIONS

Family: RHYNCHONELLIDAE Gray

Genus: **GIBBIRHYNCHIA** S. S. Buckman, 1918; emend. D. V. Ager

1905. Formenreihe des *Rhynchonella curviceps*, Rau (*pars*), p. 81.
1914. *Gibbirhynchia* S. S. Buckman, p. 1 (*nom. nud.*).
1918. *Tetrarhynchia* S. S. Buckman (*pars*), p. 41.
1918. *Gibbirhynchia* S. S. Buckman, p. 43.

Type species (by original designation): *G. gibbosa* S. S. Buckman.

Emended diagnosis. Small globose rhynchonellids, sub-trigonal to almost circular in outline, equally biconvex to almost convexi-planate in lateral view. Strong uniplication in anterior commissure, developing late. Multicostate, sometimes smooth posteriorly. Beak small, usually incurved. Foramen small, circular, hypothyrid to mesothyrid. Two deep furrow-like diductor muscle-impressions inside the pedicle valve posteriorly. Denticula (as defined by Muir-Wood, 1934) well developed. Crura short, radulifer type; crural bases not clearly differentiated. Inner and outer socket-ridges well developed. No accessory sockets.

Description. *External characters: Gibbirhynchia* comprises a series of small rhynchonellids, ranging in size up to about 16 mm. in length, 20 mm. in width and 16 mm. in thickness. All the species are either completely composed of globose individuals, or include a large proportion of such, at least as far as adult specimens are concerned. The shell in early growth-stages is equally biconvex and sub-circular in outline, becoming sub-trigonal to sub-pentagonal in outline and biconvex to almost convexi-planate in the adult stage. The anterior commissure is strongly uniplicate, the fold and sinus appearing late in development and then increasing rapidly. The dorsal fold is either not raised, or only slightly so, above the surface of the valve. The linguiform extension is usually long, rectangular to sub-trigonal, but otherwise the commissure is straight except for a slight dorsal deflection on either side of the dorsal umbo, indicating the position of the teeth. Both valves are multicostate, the costae ranging from sharply acute to well rounded. The valves are sometimes smooth posteriorly, but the costae always appear before the fold and sinus. Growth-lines are faint or absent. The beak is small and upright to strongly incurved; it usually partly hides a fairly wide delthyrium. The deltidial plates are triangular and usually disjunct or just conjunct. The foramen is small, circular, hypothyrid to mesothyrid. The beak-ridges are only faintly marked and delimit a narrow, smooth interarea.

Internal characters: (a) *Pedicle valve.* The delthyrial cavity is characteristically quadrate in cross-section. The dental lamellae are widely spaced, slightly divergent and well developed but short. They usually extend about as far forward as the plane of articulation (i.e. the plane in which the teeth project completely into the sockets). They are visible through the walls of the thinner shelled species. The lateral umbonal cavities are more or less oval in cross-section, but are largely filled with secondary shelly matter in some species. A pedicle collar can usually be distinguished. The hinge-teeth are straight, expanded dorsally and crenulated, with hollows for the reception of the inner and outer socket-ridges. Short squat denticula are developed laterally. Muscle-scars are faint and difficult to observe in the pedicle valve except for the highly characteristic deep-set posterior extensions of the diductor muscle-impressions. These appear as V-shaped grooves in the serial sections, and are particularly well marked in the thick-shelled species. A narrow central adductor impression can often be seen posteriorly (see Fig. 1).

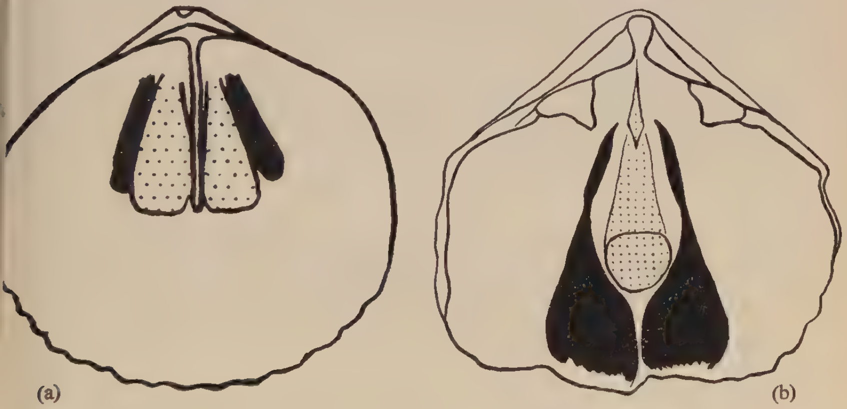


Fig. 1 (a). *Gibbirhynchia northamptonensis* (Davidson). Sketch of dorsal view of a burnt specimen from the upper part of the Marlstone Rock-bed at Byfield, Northants. Author's collection (J. 902/2). Showing muscle-scars in the brachial valve. Anterior adductor muscle-scars are shown black, posterior adductors stippled. × 4 approx. (b). *Gibbirhynchia thorncombiensis* (Buckman). Sketch of interior of pedicle valve of a specimen from a loose block below Thorncombe Beacon, Dorset. Author's collection (J. 745/9). Showing muscle-scars. Adductor muscle-scars are shown stippled, diductors black. × 6 approx.

(b) *Brachial valve.* There is no cardinal process. The hinge-plates are arched ventrally, and are clearly demarcated by ventral grooves from well-developed inner socket-ridges. Outer socket-ridges are also well developed, fitting into deep denticular cavities. There are no accessory sockets. The median septum splits away from the septalial plates progressively earlier in later forms, but always posteriorly of the plane of articulation. It persists as a ventrally tapering ridge for about one third of the length of the shell, and is sometimes hastate anteriorly. The crura originate from the distal parts of the hinge-plates, no distinct crural bases being differentiated. They are of the radulifer type, triangular or oval in cross-section. They diverge and curve slightly ventrally towards the front of the shell. The muscle scars in the brachial valve are usually very faint. The anterior adductor muscles form elongated triangular scars terminating at the end of the septum, whilst the posterior adductor scars are set closely alongside as narrow and slightly shorter parallelograms (see Fig. 1).

Species. The following species are recognised as belonging to this genus:

G. amalthei (Quenstedt).
G. batalleri (Dubar).
G. curviceps (Quenstedt).
G. gibbosa S. S. Buckman.
G. micra sp. nov.
G. muir-woodae sp. nov.
G. northamptonensis (Davidson).
G. orsinii (Gemmellaro).
G. thorncombiensis (S. S. Buckman).
G. tiltonensis sp. nov.

Of these, *G. batalleri* and *G. orsinii* are not known in Britain, and *G. curviceps* is only known as a rather rare form in the Lower Lias. All the species so far recognised in the Middle Liassic rocks of the British Isles are redescribed below.

Discussion. Buckman's original definition of the genus was as follows:

> Hypothyrid, in obese forms mesothyrid (beak short, gibbous, incurving, foramen circular, deltidial plates wide, disjunct); acutiplicate: dental plates strong, subdivergent to wedge-shaped; ventral muscle-area bulbiform; dorsal septum massive posteriorly; dorsal muscle-scars forming an obtrapeziform figure.
>
> A smooth or nearly smooth norella stage is often shown. (Buckman, 1918, p. 43).

This definition appears to apply chiefly to Buckman's type species *G. gibbosa*, which is not otherwise described. This is, unfortunately, an atypical form and one of the rarest of the British species. Buckman also listed under this genus five other species, as follows:

> Domerian: *T. amalthei* Quenstedt, *R. amalthei* Davidson, *R. liasica* Reynès, . . . ? *R. orsinii* Gemellaro.
>
> Charmouthian: *T. curviceps* Quenstedt.

Of these, *R. liasica* is considered to be a synonym of *G. amalthei* (Quenstedt) and Davidson's *R. amalthei* as synonyms of other species. *R. orsinii* and *R. curviceps* are not known in the British Domerian.

The close relationship existing between all the forms here described and their distinctiveness from contemporary forms are obvious from external features alone, but have been confirmed by a study of their interiors. Nevertheless, it is considered that *Gibbirhynchia* is reasonably close to

Buckman's other genera *Tetrarhynchia*, *Quadratirhynchia* and *Grandirhynchia*; and it is ultimately proposed to include them all in a new sub-family. The only contemporary likely to be confused with *Gibbirhynchia* is its closest ally *Tetrarhynchia*, and the differences between them may usefully be summarised here.

External characters: *Gibbirhynchia* generally possesses a globose and rounded outline, as compared with the strongly inequivalve and alate *Tetrarhynchia*. Specimens of *Gibbirhynchia* are commonly mistaken for juveniles of *Tetrarhynchia tetrahedra* (J. Sowerby), but the latter can always be easily distinguished by their wide and depressed form, and by the absence of a properly developed fold in the anterior commissure.

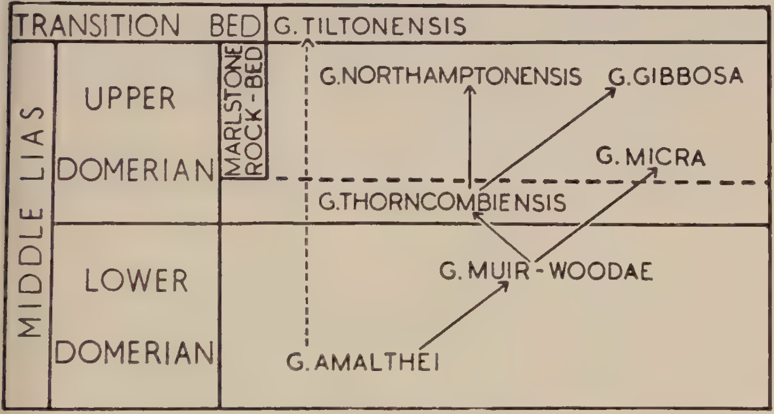


Fig. 2. The suggested relationships between the British Domerian species of *Gibbirhynchia*, and their stratigraphical distribution. (Upper Domerian = Zone of *Pleuroceras spinatum*; Lower Domerian = Zone of *Amaltheus margaritatus*)

Internal characters: In *Tetrarhynchia* the delthyrial cavity is more elongated dorso-ventrally, and the umbonal cavities are more triangular in cross-section. The median septum is shorter, not extending beyond the plane of articulation as it does in *Gibbirhynchia*. It also differs in that the anterior edge is not straight, but concave. In *Tetrarhynchia* the inner socket-ridges are not so well developed, and they are not clearly demarcated from the hinge-plates. There are, however, small accessory sockets for the reception of the denticula, which are not present in *Gibbirhynchia*.

The suggested relationships existing between the species here described, together with their stratigraphical positions in the British Middle Lias, are indicated in Fig. 2. These probably constitute only small scattered samples of a complex evolving plexus, that chanced to migrate into the British area during Domerian times.

The ancestry of this and other Domerian brachiopod genera must remain uncertain until a revision of the scarcer Lower Lias forms has been carried out. The occurrence of *Gibbirhynchia* in earlier strata has been confirmed by the identification of a few specimens close to *G. curviceps* in the Geological Survey Museum. These come from the *jamesoni* Zone of the Lower Pliensbachian. They probably represent an early 'blind-alley' offshoot approaching the *G. gibbosa* type of development. *Gibbirhynchia* probably arose via *G. amalthei* from some more generalised ancestor. Its morphology and its stratigraphical and geographical distributions suggest that *Gibbirhynchia* formed a root-stock from which several other genera arose both in Domerian and Toarcian times.

Distribution. The various species of *Gibbirhynchia* here described range vertically from near the base of the Middle Lias to the lowest beds of the Upper Lias; they range horizontally from the Dorset coast to the Humber in one direction, and via the Prees outlier to the Hebrides in the other. The Yorkshire brachiopod fauna is particularly distinctive, and the genus has not yet been identified in that area.

Though the stratigraphical positions of the species can be fixed with some accuracy, they should not be considered as zonal or sub-zonal indices, but rather as horizon markers, since they always occur in thin bands, separated by poorly fossiliferous strata in which the genus is not found. These thin and highly fossiliferous bands, notably in the Midlands ironstones, are probably of much greater lateral extent than is usually supposed. Thus these rhynchonellids are likely to be of special value in the study of the ironstones of Domerian age in the Midlands, where the Upper Domerian Marlstone Rock-bed is very variable in thickness, either as a result of non-deposition or of pre-Toarcian erosion.

Palaeo-ecology. The brachiopod faunas of the British Middle Lias can be shown to fall into four well-defined faunal provinces, each with distinctive genera and species. The genus *Gibbirhynchia*, however, is more widely distributed than its contemporaries, though its individual species are in some cases restricted. This suggests a greater range of toleration of varying environments, though like most brachiopods, *Gibbirhynchia* was most successful in lime-rich situations. In the limestones, ferruginous limestones and calcareous ironstones of various horizons and localities, *Gibbirhynchia* occurs in great abundance, especially in closely packed lenticles or 'nests', which represent original colonial associations and not merely mechanical associations by sorting on the sea-floor. This gregarious habit seems to have been more characteristic of *Gibbirhynchia* than of any of its brachiopod contemporaries.

Gibbirhynchia amalthei (Quenstedt)

Plate 1, Figs. 2 a–c; Text-figure 3

1852. *Terebratula amalthei* Quenstedt, p. 453, pl. xxxvi, fig. 17.

1856. *Rhynchonella amalthei* (Quenstedt), Oppel, p. 188.
1858. *Terebratula amalthei* Quenstedt, p. 177, pl. xxii, fig. 1.
1864. *Rhynchonella dysonymus* Seebach, p. 90.
1868. *Rhynchonella liasica* Reynès, p. 101, pl. 4, figs. 5 a–i.
1871. *Terebratula amalthei* Quenstedt, p. 65, pl. xxxvii, figs. 154–7 only.
non 1878. *Rhynchonella amalthei* (Quenstedt), Davidson, p. 200, pl. xxviii, figs. 18–21.
1905. *Rhynchonella amalthei* (Quenstedt), Rau, p. 21, pl. ii, figs. 24–30.
1918. *Gibbirhynchia amalthei* (Quenstedt), Buckman, p. 44.

Emended diagnosis. Small to medium sized thin-shelled *Gibbirhynchia*, up to about 12 mm. long, 13 mm. wide and 11 mm. thick. Sub-circular to sub-pentagonal. Almost equally biconvex. A sharp uniplication confined to the centre of the anterior commissure. Linguiform extension short and truncated dorsally. About thirty-five costae on each valve, faint in the early growth stages, becoming fairly sharp by the anterior margin. Often an early smooth stage.

Type specimens. Lectotype (here designated), an un-numbered specimen in the collection of the Geologisch-Paläontologisches Institut of the University of Tübingen, the original of Quenstedt's *Petrefactenkunde* (Brachiopoden) 1871, pl. xxxvii, fig. 155. Quenstedt's other syntypes are in the same collection.

Material and localities. The lectotype is recorded as from the *Quinqueplicaten*-banke of the Lias δ of Ohmenhausen, Württemberg. Other specimens from several different localities in Württemberg are in the collections of the British Museum (Natural History) (e.g. B. 94572–82 from Eislingen; B. 16432 from the *margaritatus* Zone at Bodelshausen, and eight specimens numbered B. 38308 from the type locality). All the specimens seen from Germany have been from the Lias δ, though Quenstedt records his species as ranging just into the Lias ε. He probably confused it with other later defined species.

Unfortunately, the German material is not accurately enough localised stratigraphically to allow correlation with this country. In Britain *G. amalthei* is rare and apparently confined to the zone of *Amaltheus margaritatus*. Since several later species approach it in form, it may represent a more persistent stock, continuing elsewhere, but not definitely known from later strata in this country. The species occurs rarely in the Eype Nodule Bed on the Dorset coast (e.g. Geological Survey specimen Ht 2148) and at a few other localities in the south-west, from about the same horizon. It occurs more plentifully in calcareous nodules in the Scalpa Sandstone of Raasay, in the Inner Hebrides, where the associated fauna also suggests a low horizon in the Domerian. Its occurrence in the borings of the Kent coalfield has already been mentioned. Insufficient specimens are known from Britain to justify definite conclusions as to geographical distribution.

Dimensions of lectotype. Length 9.8 mm., width 11.7 mm., thickness 7.7 mm.

Description. (a) *External characters*. This is a medium sized, rather thin-shelled *Gibbirhynchia*, averaging about 10 mm. in length, 11 mm. in width and 7 mm. in thickness. In all the adult specimens examined, the range in dimensions was as follows: length 8.1 to 12.1 mm., width 8.5 to 13.3 mm., thickness 6.1 to 11.2 mm. Typical forms seem to be those slightly wider than long, and slightly longer than thick.

G. amalthei is sub-circular to sub-pentagonal in dorso-ventral view, the greatest width of the shell being about half-way between the beak and the anterior margin. It is slightly globose in lateral view, both valves being strongly convex posteriorly, but sharply decreasing in thickness towards the anterior end, especially the pedicle valve. The commissure is straight all round the shell except for a sharp dorsally directed plication, confined to the centre of the anterior margin, which is not high enough, however, to break the rounded outline of the shell. The linguiform extension is short and wide, with a straight dorsal edge.

The fold and sinus do not appear before the attainment of approximately two-thirds of the normal adult size. Both valves bear from thirty-three to thirty-eight costae, five to seven of them in the region of the fold. The costae are faint in the early stages, becoming fairly sharp by the anterior margin. They occasionally bifurcate not far from the umbones. In the type specimen there is a smooth area extending from the umbones over about a quarter of each valve, but this is not always present. The beak is small, incurved and with faint beak-ridges. The foramen is mesothyrid, small and circular. The delthyrium, deltidial plates and narrow interarea are largely hidden by the beak.

(b) *Internal characters*. These are as described for the genus (see Fig. 3).

Discussion. This species is apparently the earliest *Gibbirhynchia* in the British Domerian. Of the more common British species, it most closely approaches *G. muir-woodae* and *G. thorncombiensis*, as one might expect from their stratigraphical positions. *G. amalthei* can be distinguished from the latter of these by its finer and more abundant costae, its generally smoother and smaller shells and by the position of the axes of greatest width. To a lesser degree these characters also serve to distinguish between *G. amalthei* and *G. muir-woodae*, the latter being further characterised by the much greater convexity of its brachial valve and by the sharpness of its costae.

Quenstedt first figured this species in 1852 with a single dorsal view. He published another similar figure in 1858, and finally figured eight different specimens in 1871. The original or originals of the first two figures is not known (communication from Dr. Hölder of Tübingen,

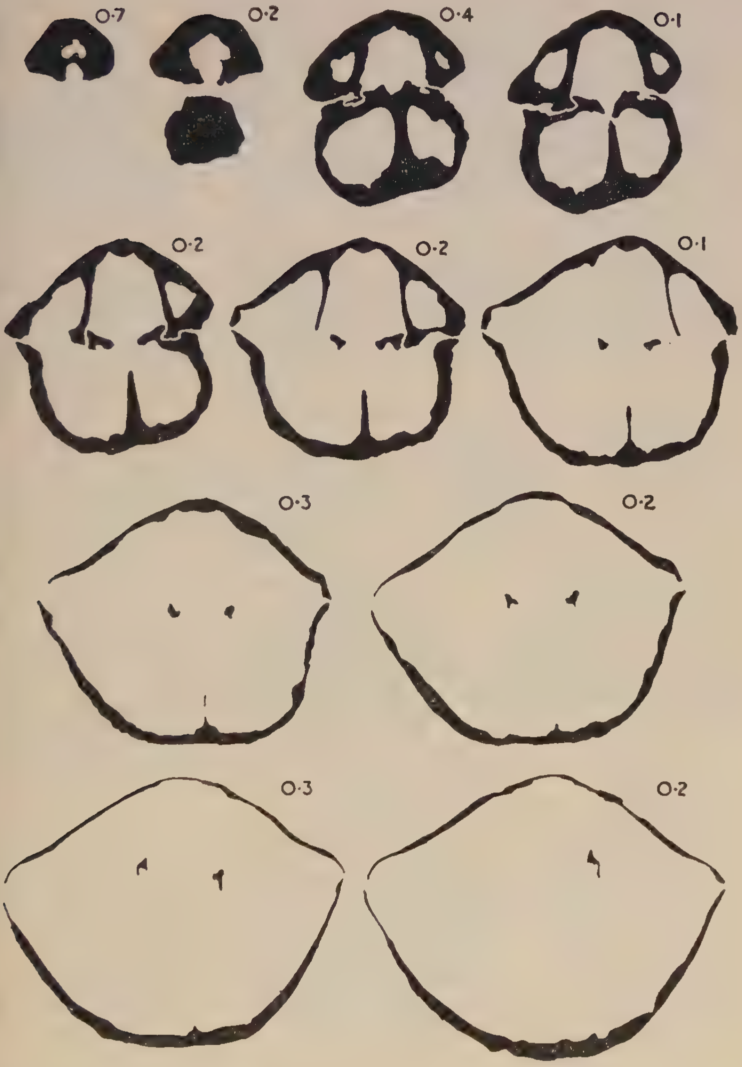


Fig. 3. *Gibbirhynchia amalthei* (Quenstedt), Lias δ: Salach, Goppingen, Württemberg. British Museum (Natural History) collection (B. 38299). A series of eleven transverse sections through the posterior part of the shell. The fourth and fifth sections show the hinge-teeth inserted in the sockets, the fourth to sixth sections show the characteristic V-shaped muscle-impressions in the pedicle valve and the last five sections show the ventrally curving radulifer-type crura. All × 6 approx. The small numbers in this and subsequent figures indicate the intervals between the sections in millimetres

1952), but the specimens figured in 1871 are still preserved in the University of Tübingen and have been examined by the author. Of these, the specimen illustrated in pl. xxxvii, fig. 155, is selected as lectotype, since it is not only the first whole specimen to be figured, but it is also one of the most typical of the numerous German specimens examined and also the one most closely resembling the figures of 1852 and 1858.

Remarks. The name '*Rhynchonella amalthei*' has been used by many authors for a considerable range of forms, chiefly as a result of the numerous and varied figures published by Quenstedt, Rau, Davidson and others. The species as here interpreted appears to be fairly common in Germany, occurring (as do all species of the genus), in closely packed nests of large numbers of individuals. It is rare in Britain, due presumably to the unsuitable conditions prevailing here at the time of its acme elsewhere.

Gibbirhynchia gibbosa S. S. Buckman

Plate 1, Figs. 1 a–c

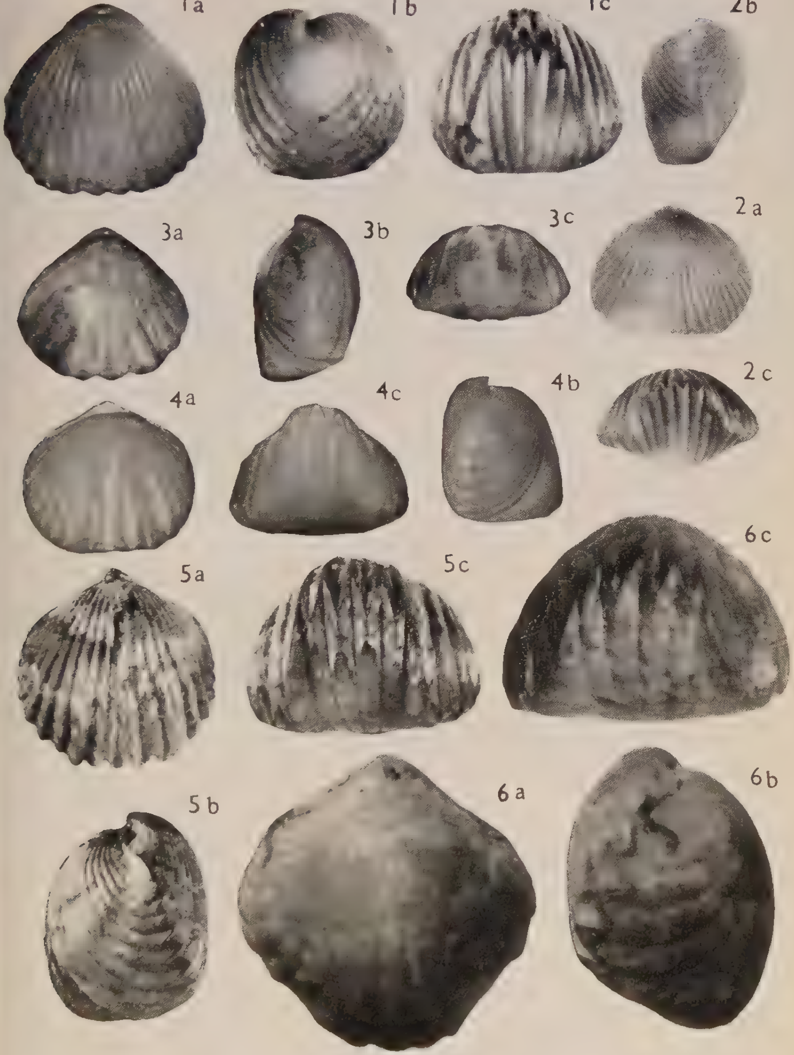
1878. *Rhynchonella amalthei* (Quenstedt), Davidson, p. 200, pl. xxviii, figs. 18–19.
1918. *Gibbirhynchia gibbosa* S. S. Buckman, p. 43, pl. 13, fig. 7.

Emended diagnosis. Medium sized *Gibbirhynchia*, up to about 15 mm. in length, 17 mm. in width and 17 mm. in thickness. Brachial valve strongly convex, pedicle valve convex with strongly incurved beak, concealing delthyrium. Foramen mesothyrid, telate. Uniplication confined to centre of anterior commissure, the sides of plication markedly convergent, linguiform extension sub-trigonal. About thirty fairly sharp costae on each valve. Median septum visible as a dark line through the thin shell.

Type specimen. Holotype (by original designation), preserved in the Geological Survey Museum (31866).

Material and locality. The holotype comes from the Marlstone Rock-bed of South Petherton, Somerset. Unfortunately the type species is one of the rarest of the British forms, but there are a few specimens in the Geological Survey Museum and in the British Museum (Natural History). The latter include a few topotypes (B. 64682–93 and B. 64702–3).

As there are now no good exposures in the type area, it is impossible to ascertain the exact horizon of the species there. The species has not been found in the few exposures remaining around the neighbouring village of Ilminster, or, surprisingly enough, in the Dorset coast sections. The only specimens it has been possible to collect *in situ* have been rare examples in the upper part of the Marlstone Rock-bed along the Cotswolds (e.g. at the old quarry near the Yew Tree Inn, at Dursley, Gloucestershire), and very occasionally in the Midland ironstone field (e.g. at King's Sutton, Northamptonshire).



GIBBIRHYNCHIA FROM BRITISH DOMERIAN

[*To face p.* 36

Dimensions of holotype. Length 11.8 mm., width 12.9 mm., thickness 11.1 mm.

Description. (a) *External characters. G. gibbosa* is a medium sized, globose *Gibbirhynchia*, ranging from about 9 to 15 mm. in length, 10 to 17 mm. in width and 8 to 17 mm. in thickness. The shell is sub-circular to trigonal in dorso-ventral view, the greatest width of the shell occurring at about two-thirds of the distance from the beak to the anterior margin. Both valves are strongly convex in lateral view, but the thickness of the brachial valve is nearly twice that of the pedicle valve. In anterior view the uniplication is seen to be confined to the centre of the commissure; it has convergent sides, and although well developed, hardly disturb the rounded outline of the shell. The linguiform extension is sub-trigonal, with a straight or curved dorsal truncation. The fold and sinus do not appear until the adult stage is nearly reached, and then develop rapidly.

The shell bears about thirty costae on each valve, of which about six are confined to the folded area. There is no posterior smooth area, the costae extend right to the umbones. They are fairly sharp at the anterior margin.

The beak is small and strongly incurved, concealing the delthyrium. The foramen is small, mesothyrid and slightly telate. The beak-ridges are faint and the interarea is narrow but clearly demarcated.

(b) *Internal characters.* The median septum is always clearly seen through the shell as a dark line, but the dental lamellae are not visible externally. The characters observed by serial grinding are as described for the genus.

Discussion. Buckman, in this case as in many others, selected as his type species an unusual and uncommon form. It differs from all the other British species of *Gibbirhynchia* in the degree of convexity of its pedicle valve, and in the extreme incurvature of the beak. It is closest to *G. thorncombiensis*, especially in the characters of costation and plication, and is probably descended from that species. It differs, however, in its greater convexity, its less triangular shape, the absence of a smooth stage, and the lateness of development of the fold and sinus. *G. northamptonensis* is also often confused with this species, but is, in fact, quite distinct in size, shape, beak-incurvature and sharpness of costae. *G. orsinii* (Gemmellaro) is fairly close to this species, especially in the characters of fold and costae, but the valves are much less inflated, and it is probable that it is a distinct form intermediate between *G. amalthei* and *G. gibbosa*, but not known in Britain.

Remarks. Owing to the scarcity of material and the poor preservation in a coarse-grained matrix of the topotypes, serial sections of this species have not proved satisfactory for reproduction. They are, however, very like those given for *G. thorncombiensis* (Fig. 5), which may be considered characteristic of the genus.

Gibbirhynchia micra sp. nov.

Plate 1, Figs. 4 a–c

Text-figures 4 a–b

Diagnosis. Small *Gibbirhynchia*, length up to about 13 mm., width up to about 15 mm. and thickness up to about 12 mm., usually much smaller. Sub-trigonal in outline, convexi-planate. Linguiform extension relatively long, almost parallel-sided. About twenty rather blunt costae on each valve, smooth posteriorly. Beak erect or sub-erect; foramen small, hypothyrid.

Type specimen. Holotype, specimen in the author's collection (J. 911/1).[1]

Material and locality. The holotype is from the lower part of the Marlstone Rock-bed at 'The Quarry', near the Yew Tree Inn, Dursley, Gloucestershire (map reference ST 740.998). Abundant specimens occur in nests at this locality between 10 and 11 ft. below the top of the exposure. The species is also abundant in the poor exposures remaining in the outliers in front of the Cotswold scarp, notably at Alderton Hill and Bredon Hill. It occurs locally in the Midland ironstone fields, for example at Adderbury, North Oxfordshire, where it is found about 8 ft. below the 'Transition Bed' in the old workings east of the village (map reference SP 485.354). It has been noted in collections from the Middle Lias of the Prees outlier in Shropshire and occurs plentifully in the Scalpa Sandstone at Tianavaig Bay in the Isle of Skye. In every case where the exact horizon is known, *G. micra* is found to occur in the middle part of the *Pleuroceras spinatum* Zone, at a slightly higher level than *G. thorncombiensis*. Geographically, it appears to be restricted to the western part of the Lias outcrop, and is unknown, to date, north-east of Banbury.

Dimensions of holotype. Length 10.2 mm., width 11.9 mm., thickness 10 mm.

Description. (a) *External characters. G. micra*, as its name suggests, is an unusually small *Gibbirhynchia*; it ranges in adult size from about 7.5 to 13 mm. in length, from 8 to 15 mm. in width, and from 5.5 to 12 mm. in thickness. It is sub-pentagonal to sub-trigonal in outline, its widest axis being slightly nearer the anterior end. The brachial valve in the adult is strongly convex, and the pedicle valve almost flat. The sides of the fold in the anterior commissure are slightly convergent or almost parallel, and the fold projects a little above the general outline of the shell. The fold and sinus develop at an earlier stage than in any other species of *Gibbirhynchia*, appearing when the brachiopod was about half grown. Both valves bear between eighteen and twenty-one costae, of which five to seven are confined to the folded area. There is usually a distinct smooth area posteriorly. The costae are slightly rounded to fairly sharp anteriorly. The beak is small and upright, or a little incurved. It has faint beak-ridges and a narrow smooth interarea. The foramen is small, circular and hypothyrid.

---

[1] Type specimens in the author's collection are to be presented to the British Museum (Natural History) at the conclusion of the work of which this forms part.

(b) *Internal characters*. These are as described for the genus, except that the characteristic paired V-shaped muscle-impressions in the pedicle valve cannot always be seen in this thin-shelled species. Some of the specimens at the type locality are preserved in a soft sandy matrix, permitting the development of the crura with a needle (see Fig. 4).

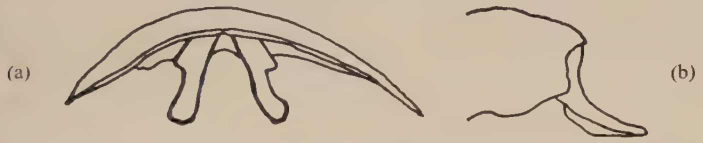


Fig. 4. *Gibbirhynchia micra* sp. nov. Topotype. Horizon and locality as for holotype. Author's collection (J. 911/42). Drawings of (a) ventral and (b) lateral views of the crura excavated with a needle. Both × 6 approx.

Discussion. *G. micra* is clearly distinguishable from the other species of *Gibbirhynchia* by its small size, its nearly flat pedicle valve and its upright, or nearly upright, hypothyrid beak. It is certainly not just a juvenile form, as are many so-called species of Jurassic brachiopods. The fully developed fold and sinus, the mode of occurrence in nests unaccompanied by larger specimens and its distinctive geographical range, all point to its being what Buckman called a 'dwarf' species. It is like *G. muir-woodae* in the flatness of its pedicle valve, and in the characters of the costae and beak. On the other hand, it approaches *G. thorncombiensis* in general form, and might easily be mistaken for that species were it not for its blunter costae and thinner shell. Some of its variants show a strong homeomorphic resemblance to *G. gibbosa*, but are distinguishable by their smaller size, thinner shell and flatter pedicle valve.

Remarks. The manuscript name '*Tetrarhynchia micra*' was given by S. S. Buckman to specimens of this form in his collection (now in the British Museum (Natural History)), but it was never figured or described. Buckman's trivial name is therefore proposed here, though the species is not attributed to the same genus.

Gibbirhynchia muir-woodae sp. nov.

Plate 1, Figs. 5 a–c

1871. *Terebratula amalthei curviceps* Quenstedt, p. 57, pl. xxxvii, fig. 160.
1878. *Rhynchonella amalthei* var. *B* Davidson, p. 201, pl. xxvii, fig. 21.

Diagnosis. Medium-sized *Gibbirhynchia* up to about 15 mm. long, 16 mm. wide and 14 mm. thick. Sub-circular in outline, somewhat truncated anteriorly. Almost convexiplanate in anterior view, with a sharp uniplication confined to the centre of the commissure. Fold low, linguiform extension long, sub-quadrate. About twenty-five sharp costae on each valve, extending to the umbones.

Type specimen. Holotype, in the author's collection, (J. 769/1).

Material and locality. The holotype comes from a shelly band in the Down Cliff Sands on the Dorset coast, a few feet above the 'Starfish Bed' (see p. 26). There is abundant topotype material in the British Museum (Natural History), mostly collected from fallen blocks beneath the cliffs. Nearly all the material seen comes from Thorncombe Beacon and the adjacent cliffs, and is variously attributed to the 'Starfish Bed' itself (e.g. British Museum specimens B. 65381–3), or to the Down Cliff Sands (e.g. B.M. specimens B. 65354–5). They are occasionally associated in blocks with the zonal ammonite *Amaltheus margaritatus*. Due to the tumbled nature of the cliff, it is very difficult to obtain specimens *in situ*. There are also specimens in the British Museum collected by J. F. Walker from the *margaritatus* Zone at North Allington, Dorset (e.g. B. 33382–4), and from the same zone as far north as Adderbury in Oxfordshire (specimens in the University Museum, Oxford). The specimens recovered from the Kent borings have already been mentioned (see p. 27). Generally speaking, however, the species is only known from a few scattered localities away from the Dorset coast.

Dimensions of holotype. Length 12.7 mm., width 13.2 mm., thickness 11.1 mm.

Description. (a) *External characters.* This is a medium-sized *Gibbirhynchia* with a relatively thin shell. In the adult stage it ranges in length from about 10 to 15 mm., in width from about 11.5 to 16 mm. and in thickness from about 9.5 to 14 mm. It is almost circular in dorsal view, the axis of greatest width being about half-way between the beak and the straight anterior margin. A strong uniplication is confined to the centre of the anterior commissure, though the fold and sinus are both very shallow, and do not break the outline of the shell as seen in anterior view. There are between twenty-three and twenty-eight costae on each valve, of which five to seven are confined to the fold and sinus. They are sharp at the anterior margin. There is no smooth area posteriorly.

The beak is small and slightly incurved, hiding the delthyrium. The beak-ridges are very poorly defined. The foramen is small, circular and sub-mesothyrid.

(b) *Internal characters.* These are generally as described for the genus, the species being somewhat unusual, however, in the relatively poor development of the median septum, which becomes merely a ridge on the inner surface of the brachial valve at a short distance from the posterior end. The dental lamellae, on the other hand, are long and rather strongly divergent for the genus. In the holotype they are about 4 mm. long, being about 0.5 mm. apart proximally, and about 3.1 mm. apart distally.

Discussion. *G. muir-woodae* is clearly intermediate between *G. amalthei* and *G. thorncombiensis* in many characters, as well as in stratigraphical position. Its intermediate nature is particularly well shown in the degree of convexity of the pedicle valve, and in the form of the fold and sinus. Two anomalous characters are (a) the poorly developed median septum and (b) the acute nature of the costae, which are closer in appearance to those of *G. northamptonensis*. It is possible, therefore, that *G. muir-woodae* represents an offshoot from the plexus connecting *G. amalthei* and *G. thorncombiensis*. Alternatively it may be that such characters as costation may be related to environment rather than phylogeny, as suggested by Lamont (1934).

Davidson (1878), states that his '*Rhynchonella amalthei* var *B*' was found by the Rev. F. Smithe in the top bed of the *margaritatus* Zone, which suggests that he was dealing with the same form. Rollier (1917), probably correctly, attributed Davidson's variety to Quenstedt's '*Terebratula amalthei curviceps*'. However, *G. curviceps* (Quenstedt) is a distinct Lower Pliensbachian form, quite unconnected with *G. muir-woodae*, and a new name is, therefore, considered necessary for this form.

The species is interesting in that it appears to be the closest of all the species of *Gibbirhynchia* to the allied genus *Tetrarhynchia*. It approaches that genus in general shape, in costation and in the reduction of the median septum, and has, in fact, often been mistaken for *T. tetrahedra* (J. Sowerby), as in the case of the Kent borings. It is, however, undoubtedly a true *Gibbirhynchia*, though it may well be near the ancestry of *Tetrarhynchia* and *Quadratirhynchia*, no examples of which have been found below the *spinatum* Zone.

Remarks. The trivial name is given in honour of Dr. H. M. Muir-Wood of the British Museum (Natural History), in recognition of the great volume of valuable work she has done on fossil brachiopoda, and of the generous help she readily gives to all who are interested in that phylum.

Gibbirhynchia northamptonensis (Davidson)

Plate 1, Figs. 6 a–c

1878. *Rhynchonella tetrahedra* var. *northamptonensis* Walker: Davidson, p. 199, pl. xxix, figs. 7–12.
non 1892. *Rhynchonella tetrahedra* var. *northamptonensis* Davidson: Walker, p. 437.
1917. *Rhynchonella northamptonensis* (Davidson), Rollier, p. 96.
1918. *Tetrarhynchia tetrahedra* var. *northamptonensis* Walker–Davidson: Buckman, p. 42.
1922. *Tetrarhynchia northamptonensis* (Davidson), Buckman, p. 435 (footnote).

Emended diagnosis. Large thick-shelled *Gibbirhynchia*, up to about 16 mm. long, 20 mm. wide and 16 mm. thick. Usually pentagonal in outline, biconvex, the pedicle valve being much more strongly convex than the brachial. Beak large, incurved, with large elliptical foramen. Strong anterior uniplication; linguiform extension long, sub-rectangular. About eighteen sharp costae starting from the umbones.

Type specimen. Lectotype, the original of Davidson's fig. 7, now in the British Museum (Natural History), (B. 27324). This was designated as lectotype by Buckman (1922) from Davidson's six syntypes, the remainder of which are also in the British Museum (BB. 12430–3).

Material and locality. The original six syntypes all came from the 'Marlstone' of Bugbrook, near Weedon, Northamptonshire. There is abundant material, including topotypes, in the collections of the British Museum (Natural History), the Geological Survey Museum, the Northampton and Leicester Museums, and in the author's own collection. Nearly all these specimens come from the Marlstone Rock-bed of Oxfordshire, Northamptonshire, Rutland and Leicestershire. The type locality is, unfortunately, no longer exposed, but the species occurs in great numbers in most of the ironstone workings of the south Midlands. It occurs less commonly along the Cotswold section of the outcrop.

Stratigraphically *G. northamptonensis* is only known from the top three or four feet of the *spinatum* Zone. It occurs commonly in a shell band near the top of the Marlstone Rock-bed, associated with the earliest dactylioceratid ammonites. It has not been found above the rock-bed.

Dimensions of lectotype. Length 15.9 mm., width 19 mm., thickness 15.3 mm.

Description. (a) *External characters.* This is the largest of the British species of *Gibbirhynchia*, with an unusually thick shell. It ranges in the adult stage from about 11 to 17 mm. in length, from about 12 to 20 mm. in width and from about 10 to 17 mm. in thickness. It is sub-circular to sub-pentagonal in outline, the widest axis of the shell being slightly nearer the front; and biconvex in lateral view, though the brachial valve is much more strongly convex than the pedicle valve. The anterior commissure is sharply uniplicate, the fold being somewhat raised above the general level of the brachial valve. The linguiform extension is long, with a straight dorsal margin and sides which vary from strongly convergent (as in the lectotype) to almost parallel. The fold and sinus first appeared when the shell had reached about half the adult size, and thereafter developed rapidly. There are about fifteen to twenty sharp costae on each valve, of which three to six are confined to the folded area. The shell is often smooth posteriorly. The beak is large and slightly to strongly incurved, with indistinct beak-ridges. The foramen is large, circular to elliptical, and hypothyrid to sub-mesothyrid. The deltidial plates are usually just conjunct.

(b) *Internal characters*. These are generally as described for the genus, but the interior is often obscured posteriorly by the development of thick secondary shelly matter, filling the delthyrial and umbonal cavities.

Discussion. *G. northamptonensis* is probably the morphological and stratigraphical equivalent of *G. gibbosa* in the Midland area. It may overlap *G. gibbosa* in the Cotswold area, but is usually distinct by reason of its greater assymmetry in lateral view, the lesser incurvature of the beak, the much sharper costae and the internal shell thickening. From its likely ancestor *G. thorncombiensis*, *G. northamptonensis* differs in its greater size, its sub-circular rather than sub-trigonal shape and in its much sharper costae.

Remarks. Davidson quotes Walker as the author of this name, but as the first published description and figures were essentially Davidson's, the name must be attributed to him.

Gibbirhynchia thorncombiensis (S. S. Buckman)

Text-figures 5–6

1892. *Rhynchonella tetrahedra* var. *northamptonensis* Davidson: Walker, p. 437.
1922. *Tetrarhynchia thorncombiensis* S. S. Buckman, p. 435.
1927. *Tetrarhynchia thorncombiensis* S. S. Buckman, pl. 1, figs. 5–6.

Emended diagnosis. Medium-sized thick-shelled *Gibbirhynchia*, up to about 15 mm. in length, 16 mm. in width and 15 mm. in thickness. Sub-trigonal in outline, the brachial valve much more convex than the pedicle valve. Linguiform extension long, with markedly convergent sides. About eighteen costae on each valve, fairly rounded at the anterior margin. Both valves are smooth posteriorly.

Type specimens. Holotype, in the British Museum (Natural History), (B. 65718). Paratype, in the same collection, (B. 65883).

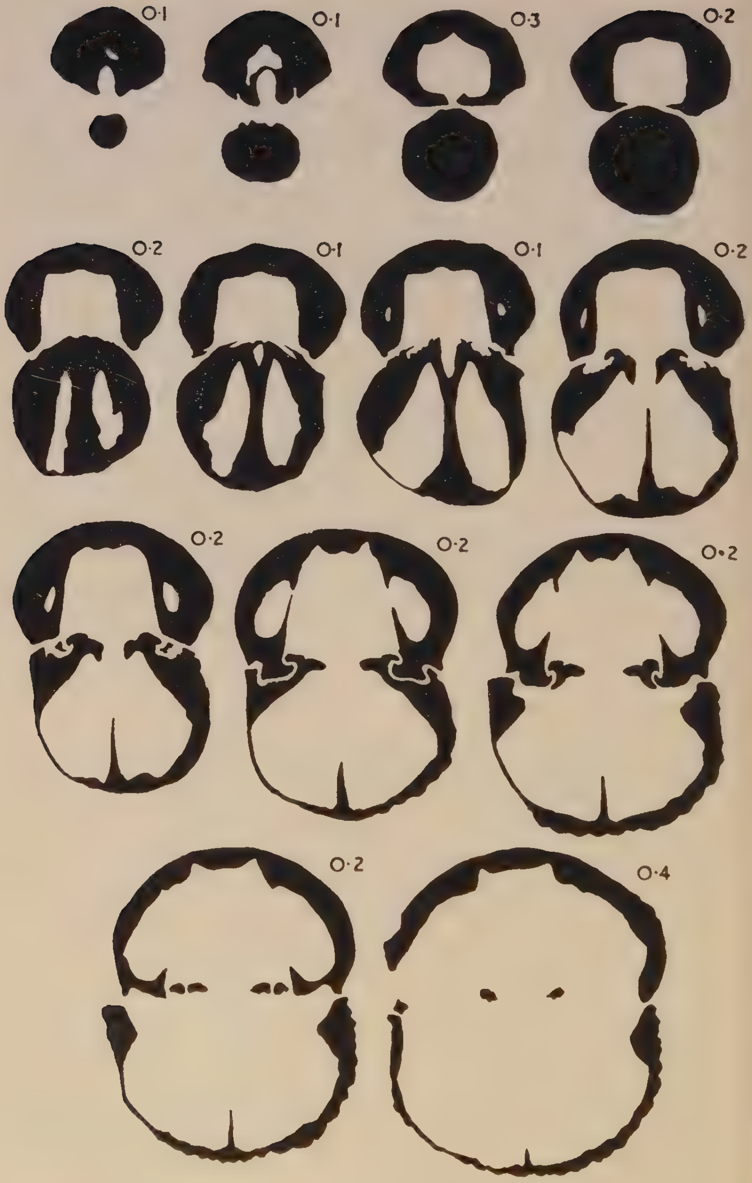


Fig. 5. *Gibbirhynchia thorncombiensis* (S. S. Buckman). '*thorncombiensis* Bed', Thorncombe Beacon, Dorset. Topotype. Author's collection (J. 723/2). A series of thirteen transverse sections through the posterior part of the shell. The tenth section shows the teeth of the pedicle valve (above) inserted into the sockets; the last four sections show the characteristic V-shaped muscle-impressions in the pedicle valve, and the final section shows the distal ends of the crura. All × 5 approx.

Material and locality. The holotype and paratype come from the '*thorncombiensis* Bed' near the top of the Thorncombe Sands, on Thorncombe Beacon, near Eype, Dorset. Abundant topotype material is preserved in the J. F. Walker collection at the British Museum (Natural History), (e.g. B. 33375–9); also in the Geological Survey Museum and in the author's collection. The species is little known away from the coast sections. Walker collected it also from what he noted as 'Stone Bed under Junction Bed' at North Allington, a short distance inland (B. 33387–9). It has also been found by the author as far north as Painswick in Gloucestershire. In every case *G. thorncombiensis* is restricted to the lower part of the *spinatum* Zone, below the level of the Marlstone Rock-bed.

The apparently restricted geographical distribution of the species is partly due to the lack of suitable exposures, and partly due to the solution of calcareous fossils from the permeable sands underlying the rock-bed.

Dimensions of types. Holotype; length 12.8 mm., width 13 mm. and thickness 12.7 mm. Paratype; length 11.1 mm. (original true length uncertain due to damage to beak), width 12.7 mm. and thickness 12 mm.

Description. (a) *External characters. G. thorncombiensis* is a medium-sized, thick-shelled species, ranging in the adult stage from about 7.5 to 15 mm. in length, from about 8 to 16 mm. in width and from about 6 to 14.5 mm. in thickness. It is sub-trigonal in outline, though tending towards pentagonal with the rounding of the anterior angles. The brachial valve is strongly convex, the pedicle valve less so. The anterior commissure is sharply uniplicate, the fold being raised slightly above the general level of the shell. The linguiform extension is long, almost triangular, with markedly convergent sides. The fold and sinus appear rather early in development, usually before the attainment of half the adult size. There are between fifteen and nineteen costae on each valve, of which five to nine are confined to the fold and sinus. They are traceable right to the umbones, but only as fine lines, anteriorly they are rounded. The shell is characterised by its smooth polished appearance at the posterior end of each valve.

The beak is small and slightly incurved, the beak ridges being well marked for the genus. The foramen is small, circular, mesothyrid and somewhat telate. The delthyrium is wide, with triangular, disjunct deltidial plates.

(b) *Internal characters.* These are as described for the genus. The shell is thicker than average, approaching the condition of *G. northamptonensis* (see Figs. 5, 6). The median septum and dental lamellae are not usually visible through the shell.

Discussion. This is probably the commonest species of *Gibbirhynchia* in British Museum collections, but nearly all the specimens come from a single horizon and locality, namely the '*thorncombiensis* Bed' on Thorncombe Beacon and the neighbouring cliffs. It may also be considered the most typical of its genus, probably coming from somewhere near the centre of the plexus here sampled.

G. thorncombiensis most closely resembles *G. northamptonensis*, the name by which it was formerly known (e.g. Walker, 1892). It is clearly distinguishable from that species by its smoothness (especially posteriorly), its blunter costae, its trigonal shape and the markedly convergent sides of its anterior fold. *G. thorncombiensis* differs even more from its immediate predecessor *G. muir-woodae*, especially in shape, in the form of the anterior fold and the sharpness of the costae.

Remarks. When Buckman described this form in 1922, he stated that he intended to figure it in 'a proposed palaeontological sequel to this paper'. Such a sequel never appeared, but he eventually published his figures in his last and much criticised paper on the Cornbrash (1927). It is not considered necessary to refigure these specimens.

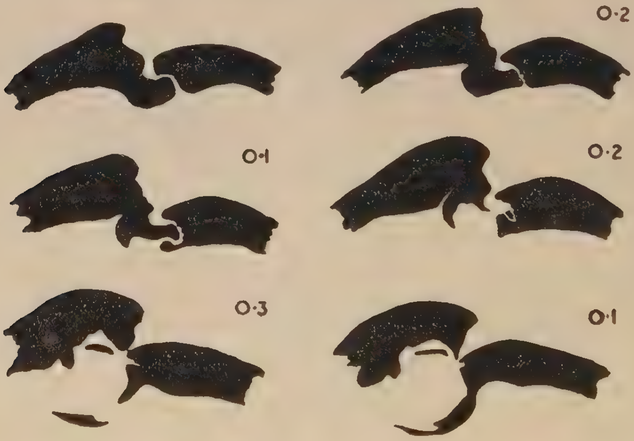


Fig. 6. *Gibbirhynchia thorncombiensis* (S. S. Buckman). '*thorncombiensis* Bed', Thorncombe Beacon, Dorset. Topotype. Author's collection (J. 723/4). A series of six longitudinal sections through the centre part of the posterior end of the shell. The second and third sections show the hinge-teeth of the pedicle valve (on the left) inserted in the sockets, and the last two sections show a curved radulifer type crus. All × 5 approx.

Gibbirhynchia tiltonensis sp. nov.

Plate 1, Figs. 3 a–c

Text-figure 7

1878. *Rhynchonella amalthei* var. *A* Davidson, p. 201, pl. xxviii, fig. 20.

Diagnosis. Small to medium-sized, thin-shelled *Gibbirhynchia*, up to about 14 mm. in length, 17 mm. in width and 12 mm. in thickness. Sub-trigonal to sub-pentagonal in outline, depressed, brachial valve more convex than the pedicle valve. Linguiform extension short, wide, almost rectangular. Foramen fairly large, circular, mesothyrid. About seventeen rounded costae on each valve. No deep diductor scars in the pedicle valve.

Type specimens. Holotype, specimen in the author's collection (J. 790/1) from the 'Transition Bed' (horizon of *Tiltoniceras acutum*, see p. 27), at the disused quarry west of the railway at Tilton, Leicestershire (map reference SK 756.057). Paratype, specimen in Mr. J. F. Jackson's collection in the National Museum of Wales, Cardiff (26.135.G.136.1), from Jackson's 'At' layer in the Junction Bed on Doghus Cliff, Dorset (see Jackson, 1926).

Material and locality. Specimens occur in abundance wherever the 'Transition Bed' is exposed in the English Midlands, most notably in north Oxfordshire and south Leicestershire. Elsewhere, specimens are extremely rare, due probably to the absence of this thin band from the succession. There are few specimens in the main London collections, though there are plenty in Beeby Thompson's collection at the Northampton Museum, in the Leicester Museum and in the author's collection.

Stratigraphically *G. tiltonensis* appears to be confined to the lowermost bed of the Upper Lias in Britain. In the Midlands this is represented by the 'Transition Bed', resting (where preserved) immediately on the Middle Lias Marlstone Rock-bed. The species also occurs at about the same level in Jackson's 'At' layer on the Dorset coast. This suggests a formerly more extensive distribution, much of the record having been lost as a result of early Toarcian erosion.

Dimensions of types. Holotype, length 10.2 mm., width 11.7 mm., thickness 7.9 mm. Paratype, length 12.6 mm., width 16 mm., thickness 11.3 mm.

Description. (a) *External characters. G. tiltonensis* is usually a small thin-shelled species, the normal adults in the Midlands ranging from about 7.5 to 11.5 mm. in length, from about 8 to 13 mm. in width, and from about 5 to 10.5 mm. in thickness. The rare specimens found on the Dorset coast are all larger, ranging up to about 14 mm. in length, 16.5 mm. in width and 12 mm. in thickness. This phenomenon of relatively greater size at the south-west end of the outcrop is characteristic of many brachiopod species in the Domerian.

G. tiltonensis is broadly trigonal in outline with rounded antero-lateral angles, the widest part of the shell being close to the anterior margin. In lateral view the shell is usually depressed, though some variants are more globose, especially in the brachial valve. The anterior margin is uniplicate, the fold and sinus developing late and hardly breaking the line of the shell as seen in anterior view. The linguiform extension is broad and short, with convergent sides and a straight dorsal margin. The costae are well marked and rounded throughout most of their length, in some cases becoming more acute at the anterior margin. A small smooth area is often present posteriorly. There are between fifteen and twenty costae on each valve, of which three to six are confined to the fold and sinus. The beak is small, rounded and incurved, with only traces of beak ridges. The foramen is fairly large for the genus, circular and mesothyrid. The wide delthyrium is usually concealed by the beak.

(b) *Internal characters*. These are as described for the genus, except for the absence of the characteristic V-shaped muscle-impressions in the pedicle valve (Fig. 7). The long median septum is usually clearly visible through the shell, as are the dental lamellae, which are short and divergent.

Discussion. There is some doubt whether this species should be included in the genus *Gibbirhynchia*. Though resembling the other species in most characters, it differs from them in others, notably in its broader and more depressed form, its rounded costae and in the absence of the deep diductor muscle-impressions in the pedicle valve. In features such as the depressed nature of the brachial valve posteriorly, *G. tiltonensis* approaches the group of Toarcian forms centred around '*Rhynchonella*' *moorei* Davidson. However, though the selected types may be said to be truly typical of the species, if the whole range of variation in *G. tiltonensis* is considered, it is found to come much closer in form to species such as *G. gibbosa* and *G. amalthei*. It is not considered that *G. tiltonensis* is sufficiently distinctive to justify the erection of a new genus or sub-genus, though such may follow a revision of the Upper Lias rhynchonellids as a whole.

G. batalleri (Dubar) superficially resembles this species, but its long smooth stage, the obtuseness of its apical angle and its sharp costae, make it quite distinct.

Remarks. The trivial name is taken from the village of Tilton, in Leicestershire, where the species is particularly common, and where the holotype was collected.

G. tiltonensis differs from the other species here described in that it occurs as scattered individuals rather than as closely packed 'nests'. This may be connected with a different mode of life, or it may be the result of disturbance by currents on the sea-floor. Either possibility might also explain the unusual associated fauna, notably ammonites and gastropods, which are rarely found in the proximity of the earlier species of the genus.

Davidson's '*Rhynchonella amalthei* var. *A*', which is considered to be a synonym of this species, is said to be from the '*Am. communis*' Zone of the Upper Lias.

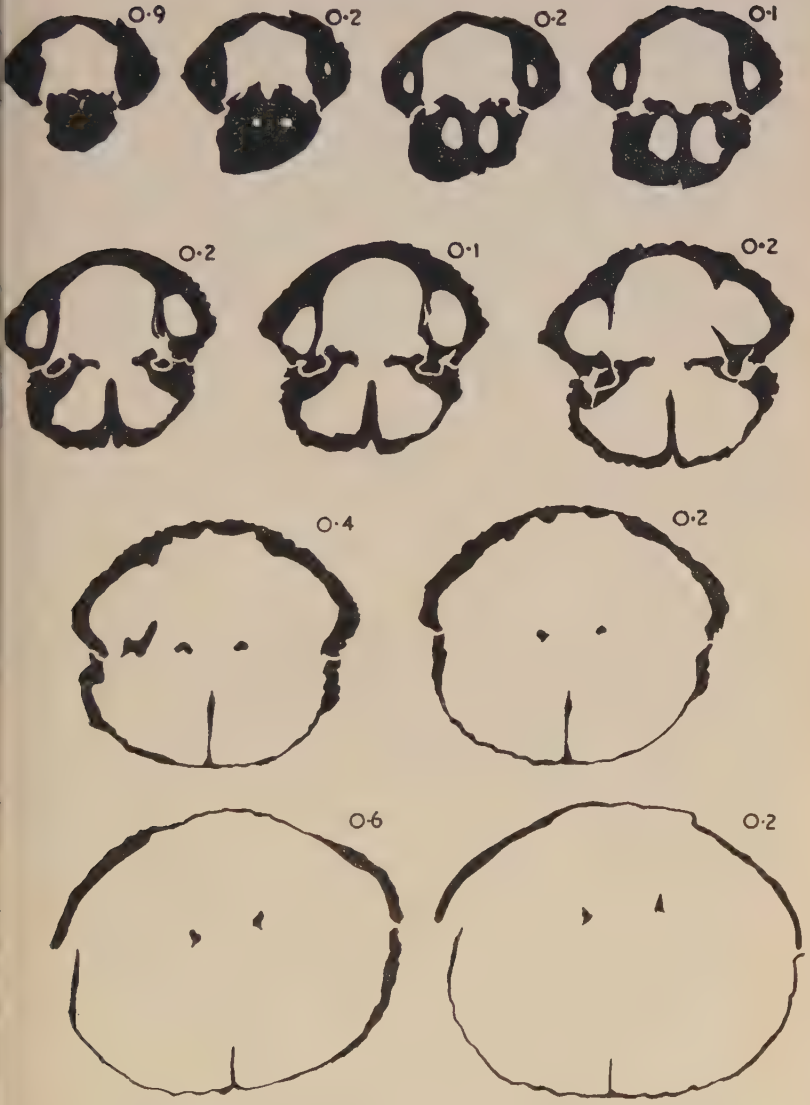


Fig. 7. *Gibbirhynchia tiltonensis* sp. nov. 'Transition Bed', disused quarry, west of railway at Tilton, Leicestershire. Topotype. Author's collection (J. 790/3). A series of eleven transverse sections through the posterior part of the shell. The sixth and seventh sections show the hinge-teeth inserted into the sockets and the last four sections show the ventrally curved radulifer-type crura. All × 7 approx.

ACKNOWLEDGMENTS

The author would like to express his gratitude to Dr. H. M. Muir-Wood of the British Museum (Natural History) for her invaluable advice and encouragement during the preparation of this paper, and to Dr. Gwyn Thomas for his critical reading of the manuscript. Considerable help has been provided by those responsible for a number of different collections, notably Mr. R. V. Melville, Dr. H. Hölder, Mr. E. F. Owen and Mr. W. E. Howarth. The author was also privileged in being allowed to examine the collections of Mr. J. F. Jackson and Mr. A. Hallam.

Part of the expenses of the investigation were met by a grant from the Central Research Fund of London University. Finally, thanks are due to Mr. J. A. Gee for assistance with the photography and to the author's wife for assistance in every aspect of the work.

EXPLANATION OF PLATE

All the specimens are reproduced at twice natural size. The registered numbers are given in parentheses. In each case (a) is the dorsal view, (b) the lateral view and (c) the anterior view.

Fig. 1. *Gibbirhynchia gibbosa* S. S. Buckman. Holotype. Marlstone (presumably the Marlstone Rock-bed) of South Petherton, Somerset. Geological Survey Museum specimen (31866).

Fig. 2. *Gibbirhynchia amalthei* (Quenstedt). Lectotype. '*Quinqueplicaten*-banke' of the Lias of Ohmenhausen, Württemberg, Germany. The original of pl. xxxvii, fig. 155 in Quenstedt (1871), in the collection of the Geologisch-Paläontologisches Institut in the University of Tübingen (un-numbered).

Fig. 3. *Gibbirhynchia tiltonensis* sp. nov. Holotype. 'Transition Bed' (top of the Marlstone Rock-bed), from disused quarry near Tilton station, Leicestershire, on north side of main road, just west of railway line (map reference SK 757.057). Author's collection (J. 790/1).

Fig. 4. *Gibbirhynchia micra* sp. nov. Holotype. Lower part of the Marlstone Rock-bed, 10–11 ft. from top, in old quarry about 330 yds. north-west of Yew Tree Inn, Dursley, Gloucestershire (map reference ST 740.998). Author's collection (J. 911/1).

Fig. 5. *Gibbirhynchia muir-woodae* sp. nov. Holotype. Shelly band near the base of the Down Cliff Sands, a few feet above the 'Starfish Bed', in lower part of cliff section, just east of the highest point of Thorncombe Beacon, near Eypemouth, Dorset. Author's collection (J. 769/1).

Fig. 6. *Gibbirhynchia northamptonensis* (Davidson). Lectotype. Marlstone (presumably the Marlstone Rock-bed), of Bugbrook, near Weedon, Northamptonshire. British Museum (Natural History) specimen (B. 27324).

REFERENCES

BUCKMAN, S. S. 1914. Genera of some Jurassic Brachiopoda. London, 1–2.

——. 1918. The Brachiopoda of the Namyau Beds, Northern Shan States, Burma. *Palaeont. Ind.* (N.S.), **3** (2) (1917), 1–299, pls. 1–21.

——. 1922. Jurassic Chronology II. Certain Jurassic Strata near Eypesmouth (Dorset). *Quart. Journ. Geol. Soc. Lond.*, **78**, 378–457.

——. 1925. Type Ammonites, London, **5**, 1–88, 200 pls.

——. 1927. Some faunal horizons in the Cornbrash. *Quart. Journ. Geol. Soc. Lond.*, **83**, 1–37, pl. 1.

DAVIDSON, T. 1874–82. A monograph of British fossil Brachiopoda. Supplement to Brit. Jur. & Trias. Brach. *Monogr. Palaeont. Soc.*, London, 4, 73–241, pls. 9–29.

DAY, E. C. H. 1863. On the Middle and Upper Lias of the Dorsetshire Coast. *Quart. Journ. Geol. Soc. Lond.*, **19**, 278–97, 5 text-figs.

DUBAR, G. 1931. Brachiopodes liasiques de Catalogne et des régions voisines. *Bull. Inst. Catalon. Hist. nat.*, **31** (4), 3–80, pls. 1–5.

GEMMELLARO, G. G. 1874. Sopra alcune Faune Giuresi e Liasiche di Sicilia, Palermo, pt. 3, 53–112, pls. 10–11.

JACKSON, J. F. 1922. Sections of the Junction-Bed and contiguous deposits. Appendix in Buckman (1922), 436–48.

———. 1926. The Junction-Bed of the Middle and Upper Lias on the Dorset Coast. *Quart. Journ. Geol. Soc. Lond.*, **82**, 490–524, pls. 33–4.

LAMONT, A. 1934. Lower Palaeozoic Brachiopoda of the Girvan District. *Ann. Mag. Nat. Hist.*, ser. 10, **14**, 161–84, 5 figs.

LAMPLUGH, G. W., F. L. KITCHIN & J. PRINGLE. 1923. The concealed Mesozoic Rocks in Kent. *Mem. Geol. Surv.*, i–iv, 1–248, pls. 1 & 2.

MUIR-WOOD, H. M. 1934. On the internal structure of some Mesozoic Brachiopoda. *Phil. Trans. Roy. Soc. Lond.*, (B) **223** (505), 511–67, pls. 62–3.

———. 1936. A monograph of the Brachiopoda of the British Great Oolite. Series I. *Monogr. Palaeont. Soc.*, London (1935), i–ii, 1–144, pls. 1–5.

OPPEL, C. A. 1856–8. Die Juraformation Englands, Frankreichs und des südwestlichen Deutschlands, Stuttgart, 1–857, pl. 1. 1 map.

QUENSTEDT, F. A. 1851–2. Handbuch der Petrefactenkunde, Tübingen, i–iv, 1–792, atlas 62 pls.

———. 1856–8. Der Jura, Tübingen, 1–823, atlas 103 pls.

———. 1868–71. Petrefactenkunde Deutschlands, 2, Brachiopoden, Leipzig, 1–748, atlas 25 pls.

RAU, K. 1905. Die Brachiopoden des mittleren Lias Schwabens. *Geol. u. Palaeont.*, Abhandl. 10 (5), 1–94, pls. 1–4.

REYNÈS, P. 1868. Essai de géologie et de paléontologie Aveyronnaises, Paris, 1–109, pls. 1–6.

ROLLIER, L. 1917. Synopsis des Spirobranches (Brachiopodes) Jurassiques Celto-Souabes, 2. *Mém. Soc. paléont. Suisse*, **42**, 71–184.

SEEBACH, K. VON. 1864. Der Hannoversche Jura, Berlin, 1–158, pls. 1–10, 1 map.

SPATH, L. F. 1942. The Ammonite Zones of the Lias. *Geol. Mag.*, London, **79**, 264–8.

WALKER, J. F. 1892. On Liassic sections near Bridport, Dorsetshire. *Geol. Mag.*, London, **9**, 437–43, 1 fig.

WHITEHEAD, T. H. *et alia*. 1952. The Liassic Ironstones. *Mem. Geol. Surv.*, i–viii, 1–211, pls. 1–8.

The Relief and Drainage Evolution of the Blean

by A. COLEMAN

Received 11 September 1952

CONTENTS

1. STATEMENT OF THE PROBLEMS ... ... page 52
2. DRAINAGE DIRECTION 53
3. THE PRESERVATION OF THE BLEAN AS A PLATEAU 61
4. CONCLUSION 63
REFERENCES 63

ABSTRACT: The Blean plateau is of morphological interest because it exhibits two features which are unusual in clay country. Firstly, there is a great regularity of direction in its drainage pattern, and secondly, as a regional unit, the Blean has proved relatively resistant to erosion. Each of these characteristics can be explained by reference to the denudation chronology of the area. The Blean has been completely traversed by the River Stour which has migrated laterally across it. The minor streams owe their parallelism to a common origin as left bank tributaries of the Stour, although they are now isolated from it. Their capture history also follows logically from this origin. The preservation of the Blean as an upstanding plateau is related to the extension of the minor streams parallel with the coast in the wake of the migrating Stour. Long portions of their courses thus remain higher than those of streams which run directly to the coast, and this extra height is reflected in the altitude of the Blean as a whole.

1. STATEMENT OF THE PROBLEMS

THE BLEAN lies on the north coast of Kent between the Isle of Sheppey and the Isle of Thanet. It is a roughly rhomboidal tract of London Clay fringed narrowly and incompletely with Lower London Tertiaries. It is contrasted with the areas immediately to the east and west, since there the London Clay has been eroded and the Eocene consists chiefly of the irregular outcrops of Thanet Sand.

The relief map (Fig. 1) shows a longitudinal alternation of ridge and valley with a strong east-north-east grain. The interfluves are flat and the general appearance is of a plateau declining gently from a height of about 400 ft. in the south-west corner. The chief exception to this simple pattern is the Herne Depression, a low-lying rectangular area in the north. This is open to the sea between Whitstable and Herne Bay, and on the other three sides is bounded by sharply rising ground. Within this depression the streams flow north-north-east instead of east-north-east.

There can now be recognised two peculiar features of the area. The first is the compactness of the Blean as a unit, leading us to ask why the

London Clay has been preserved as an upstanding plateau here but entirely removed to the east and west. The second characteristic is the constant presence of two dominant directions in the relief and drainage-pattern.

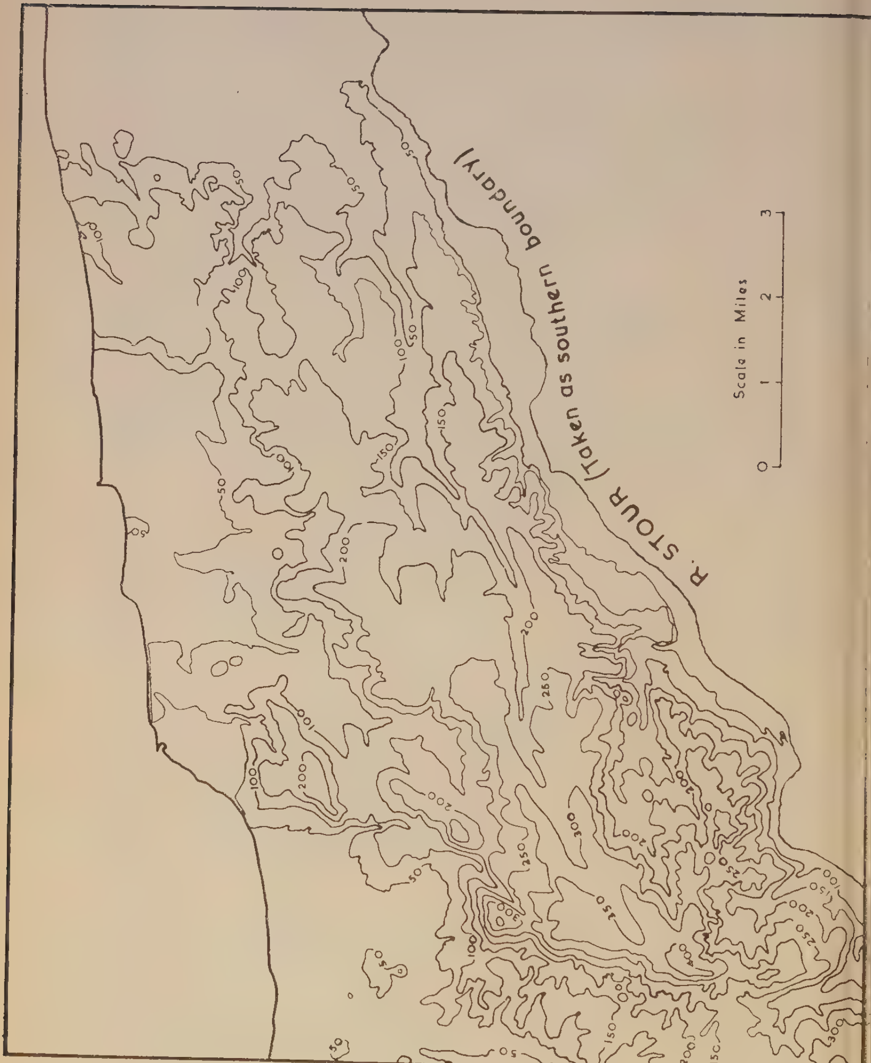
This paper is an attempt to explain these two problems. Each of them is the type of feature which can often be accounted for in terms of structure, and accordingly an attempt has been made to elucidate the local structure by means of a stratum-contour map of the Eocene base (Fig. 2). This shows two parallel anticlines with complementary synclines occupying the western half of the Blean and pitching towards its centre, where there is an arcuate trough. This trough is flanked on the north-east, first by the end of the Thanet anticline, and beyond by a short north–south monocline. The combined result of these structures is to depress the London Clay stratum in relation to the Tertiary tracts to either side, so rendering it less vulnerable to erosion. This is a partial explanation of the first problem—the preservation of the Blean as a unit—but it is not the whole solution, as will be shown presently. The second problem—the origin of the regional grain—is clearly *not* solved by reference to structure, but a more comprehensive statement of it is now possible.

2. DRAINAGE DIRECTION

The streams follow the structural axes for an aggregate length of seven miles, which is 10½ % of the total drainage-length of the Blean. Over most of the area, however, they are markedly discordant with the structure, as is generally the case in the London Basin. For example, the Stour crosses the main Blean trough at Upstreet, and the Sarre Penn behaves similarly at Chislet Park; the Wantsum crosses the Thanet anticline, and the other small streams of the northern Blean pursue their paths to the sea following both dip and strike directions locally, but often accordant with neither. It seems unlikely, therefore, that the seven miles of harmony between the drainage and the disposition of the strata represent anything more than adventitious agreement.

Nevertheless one cannot dismiss the stream-pattern of the Blean as simply dendritic. A comparison with the irregular river net of any typical tract of clay immediately throws fresh emphasis upon the two recurring directions already noted in the Blean streams. Quantitative analysis shows that the east-north-east direction accounts for 41.5 % of the total sixty-six miles, while the north-north-east reaches account for 26.6 %. Only one third falls outside these two categories, and this is composed only of insignificant tributaries.

Patently, the drainage-system has been subject to guidance, and since this guidance is not structural, some alternative cause must be sought. The present topography offers no clue as to the nature of this cause; it is,

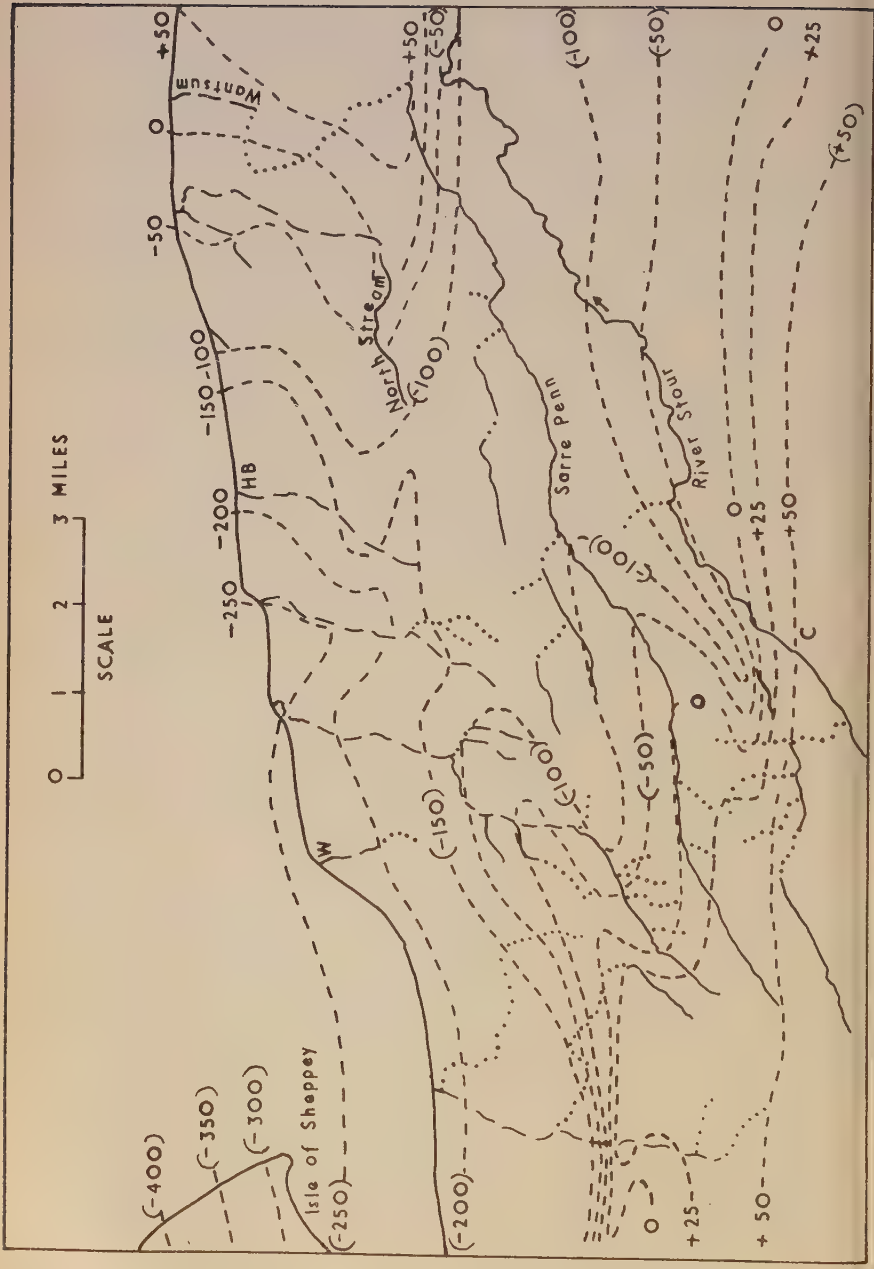

R. STOUR (Taken as southern boundary)
Scale in Miles
0
1
2
3
50
100
150
200
250
300

therefore, necessary to adopt the genetic approach and reconstruct, as far as possible, the evolution of the drainage-system. River-terraces must be examined in order to discern the former positions of the streams. The physical map alone is inadequate for this purpose: it presents the oversimplified picture already drawn, and allows the more delicate detail to slip through the coarse mesh of the contour-interval. Close field scrutiny has been carried out, and upon this a denudation chronology of the area has been based.

A brief reference must be made to Coleman (1952) to which this paper is the sequel. The field evidence was there reproduced in map form, and it was demonstrated that the Stour had persistently migrated eastward from the western summit of the Blean to beyond its eastern margin. In its passage it produced a flight of broad north–south terraces at very close vertical intervals. These surfaces are now preserved upon the interfluves and are the cause of the general plateau-like character. They are related to old sea levels at 400 ft. (approx.), 350 ft., 300 ft., 265 ft., 205 ft., 160 ft., 125 ft. and 100 ft., and also to two lower stillstands which are termed the Upper and Lower Reculver stages. The surfaces have been transversely dissected by the minor, east-north-east, streams which are responsible for the detailed modelling of the area, and have themselves left small terraces. The terrace evidence is here presented in the form of a block-diagram (Fig. 3).

The natural parallelism of the minor streams can only spring from a simple uniformity of origin. Though they now reach the sea independently of the Stour, they were formerly its left-bank tributaries. As the parent river migrated eastward it exposed a series of abandoned flood-plains. These acted as initial surfaces across which the young family of left-bank affluents extended themselves in unison. They were not absolutely at right angles to the trunk stream, being directed slightly downstream. Eventually, they became superimposed through the alluvia on to the London Clay beneath.

Each tributary was compounded of a series of segments added stage by stage as the Stour migrated. The age of each segment can be determined within very narrow limits. The maximum limit is controlled by the fact that no reach can be older than the particular terrace of the Stour which it traverses, for no pre-existing stream could have survived the relentless passage of the Stour as it swept the landscape clean and laid down a fresh gravel carpet as a datum-plane for later dissection. In many cases a minimum age can also be set, on the evidence of the small terraces formed by the tributaries themselves. At first the streams were not large enough to cut such features, but, as they lengthened, their power and volume increased and they were able to cut and build small flats, especially near their confluences with the Stour. The 205-ft. stage is the first at which such evidence is normally found.


SCALE
0
1
2
3 MILES
+50
Wantsum
0
-50
North Stream
(-100)
-150-100
-200
HB
-250
W
+50
(-50)
(-100)
(-50)
0
+25
(+50)
Sarre Penn
River Stour
0
+25
+50
(-100)
C
0
(-50)
(-100)
(-150)
(-400)
(-350)
(-300)
Isle of Sheppey
(-250)
(-200)
0
+25
+50

To assist examination of the individual streams the drainage may be divided into three basins (Fig. 4). In the south is the Harbledown Stream which was influenced by the proximity of the Stour. In the north is a group of streams which have been influenced by the proximity of the sea. In the centre is the Sarre Penn system. The Sarre Penn is one of four streams which flow east-north-east from the summit of the Blean, and is alone among the four to maintain this same direction across the whole width of the area. The flats upon which its reconstruction is based all lie close to the river, indicating that it has not roved far from its present line during the whole period of its development. Its tributaries also show four short east-north-east reaches.

The growth stages of the Sarre Penn form a complex sequence which can be most simply described as a logical 'chain-reaction' of stream extensions and diversions. Essentially, three parallel streams traversed the central Blean and two of them underwent dismemberment to the profit of the third, the Sarre Penn itself. The middle member is now divided into two parts, and the northerly one into three, of which one no longer feeds the Sarre Penn system. The disintegration has been progressive: the streams' upper courses were broken before their lower extensions were formed and it is easy to see why this must inevitably have been so. The streams were so close that they could co-exist only so long as none of them had cause for strong lateral corrasion. Extension at the lower end meant, in due course, incision in the middle and upper reaches when the tributaries had adjusted themselves to the lower base-level at their entry to the Stour. With such incision came the development of valley-side gullies, and competition between these would give opportunity for capture. In the earlier stages the northern member was diverted northward, but after this the Sarre Penn assumed the rôle of master stream and now provides the sole outlet for the integrated drainage system. Five captures can be detected within the basin, and each is witnessed by an elbow of capture, a beheaded stream and a windgap or equivalent feature which allows the episode to be dated. Fig. 4 illustrates the capture-sequence which can be built up in detail, stage by stage.

The last two maps in Fig. 4 depict changes in the northern Blean also. Both the Longreach and the North Streams must have had very similar histories, but the evidence pertaining to the latter is more abundant, and this only will be discussed here. The stream itself is now no more than a shrunken remnant on the eastern margin of the Blean, but terraces of the 100-ft. and certain earlier stages can be traced west of its present source for several miles, through a windgap at Herne, along the southern edge of the Herne Depression, and then through a large and conspicuous windgap in the western boundary of the Blean. It follows that the original source was well to the west of that boundary: in fact, the Blean must have formerly

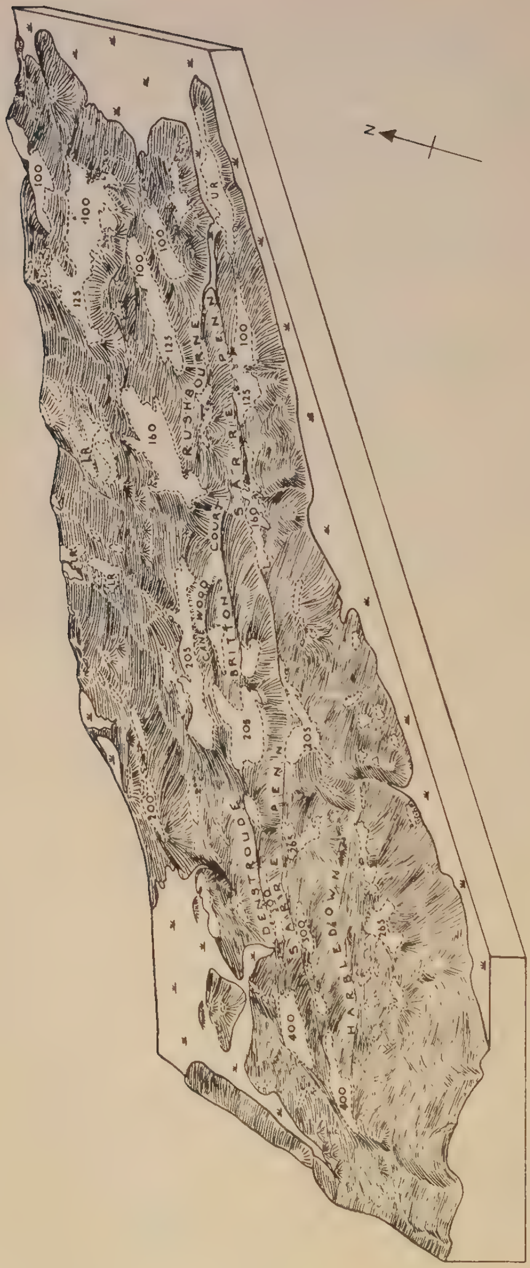


Fig. 3. Block diagram showing erosion-surfaces

possessed a considerable wing of high territory adjoining its north-west quadrant. Its severance from the kindred clay-tract of Sheppey could hardly have begun.

Up to and including the 100-ft. period the North Stream continued to extend itself in the wake of the retreating Stour, but the Reculver period witnessed a complete reversal in this trend, and stream dismemberment became the dominant form of change. The Herne windgap at 90 ft. indicates a first diversion, but this is far from a simple case, as one searches in vain for an elbow of capture, or indeed for any trace of the diverted reach. The little Herne Bay stream is in the right position to have effected this capture, but it no longer retains the spoils of piracy. It is, in fact, hardly more than a trickle, yet it must formerly have possessed a sufficient volume to have carved the eastern wall of the depression, and such extra volume is evidently reconcilable with the hypothesis of capture. As the stream cut back headward at the stimulus of coastal retreat, it could not avoid intersecting the line of the North Stream and thus diverting it. While this pattern of drainage lasted (Fig. 4F) the southern and eastern walls of the depression were undercut, and its floor roughly flattened at the Upper Reculver level. This floor has since been dissected by the north-north-east streams, but relics of it are preserved as small flats along the modern interfluves.

Resembling the Herne Bay Stream in their late origin and rapid headward erosion, all of these north-north-east streamlets were as well fitted as the latter to intercept the North Stream, and it appears that each in turn did, in fact, act as pirate. When reinforced by this additional supply of water, they were able to carve out broad Lower Reculver terraces which are much too large to be their unaided work in their present condition. Once the stream at Whitstable had effected a similar interception, the North Stream could no longer enter the Blean at all. Its surviving headwaters were confined to the Swale basin, and the broad windgap, noted above, was left abandoned. But meantime the normal ridge and valley character of the northern Blean had been destroyed and replaced by the present marked depression with its north-north-east streams.

It is now clear that these north-north-east streams are simply the normal right-bank tributaries of those flowing east-north-east. The coastal ones must have originated as the affluents of a river which lay offshore of the present coast, and so fall into pattern, despite their greater size. The rapid recession of the coast, which locally exceeds three feet per annum, indicates that room for such a stream must have existed in the quite recent past, and in more remote times there may have been several. Their valleys would have been progressively washed away as the sea advanced southward, and their right-bank affluents brought into direct contact with base level, with consequent rejuvenation and headward erosion. The Bishopstone

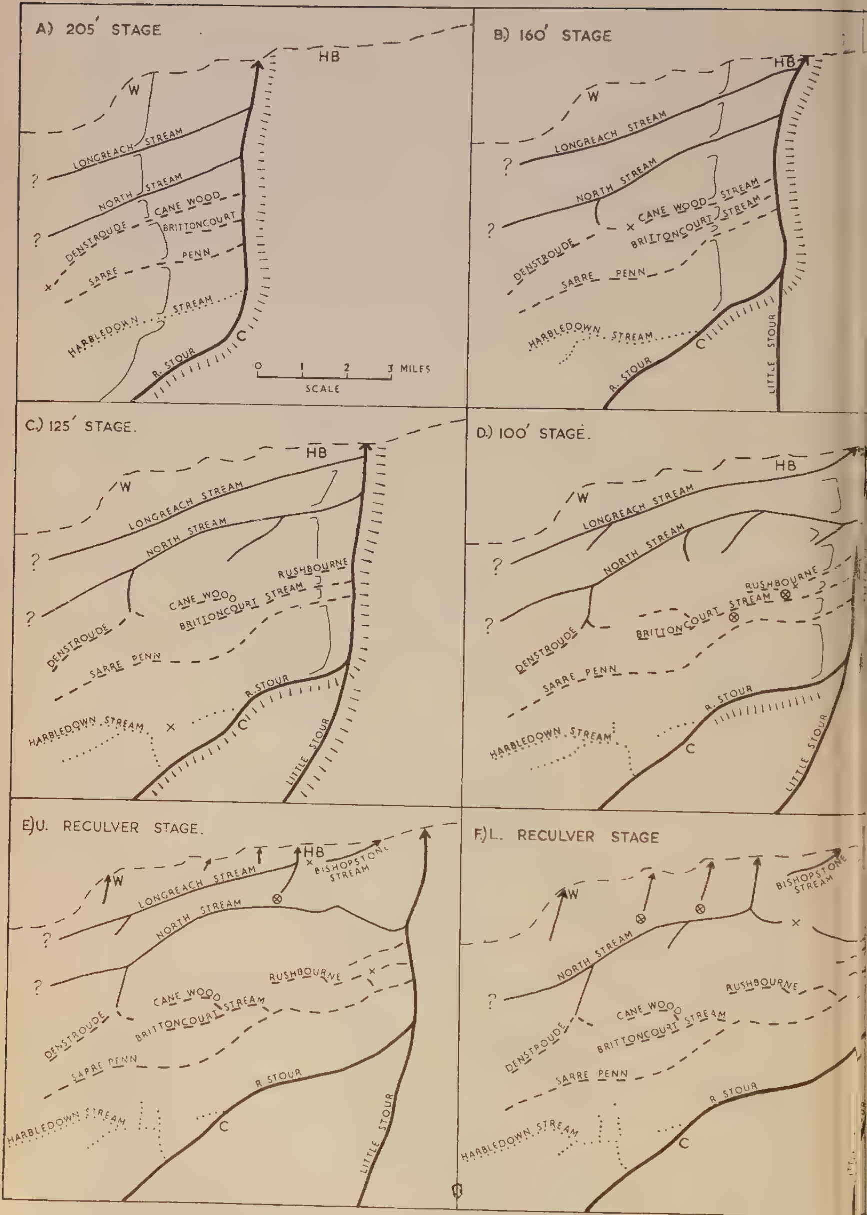


Fig. 4. The growth stages of the drainage-system

———Streams of the northern Blean system
------Streams of the central Blean, or Sarre Penn, system
........Streams of the Harbledown system

× Site of windgap
⊗ Site of incipient ca

C. Canterbury W. Whitstable H.B. Herne Bay ravine, a classic Eocene locality near Herne Bay, is a modern example of similar rejuvenation, which convincingly indicates how the formerly tiny tributaries could be endowed with the power to effect the captures described.

The two dominant valley-directions in the Blean have now been shown to be an integral part of a coherent pattern of drainage development. The same facts also have an illuminating bearing on the other problem under consideration, namely the preservation of the Blean as a compact plateau.

3. THE PRESERVATION OF THE BLEAN AS A PLATEAU

Fig. 5, a section running along the Sarre Penn and the interfluve to the south of it, demonstrates that the progressive eastward extension of the streams has in general restricted their depth of incision, and so allowed the preservation of the clay-cover, which has not been preserved to the east or west. The clay is left white and the underlying beds shaded, in order to portray more clearly two height comparisons which the diagram is designed to make. Firstly, it compares the east-north-east streams (exemplified by the Sarre Penn thalweg) with the simple dip-streams to the west. The change in valley-direction at the watershed between the two brings the high source reach of the former into juxtaposition with the low middle reach of the latter. They are, therefore, separated by a topographic break, and it is the coincidence of this break with the structural pitch that makes the western boundary of the Blean so distinct.

The second comparison is between the existing east-north-east streams, and the theoretical dissection which would have occurred if the Stour had not migrated. Had the Stour remained in its earliest position, it would have incised its valley vertically down to present base-level. It would have cut through the London Clay and have removed it from the interfluves on either side. In that case there would have been no homogeneous clay-plateau, even despite the local structural depression of the clay. We may take another theoretical case in which the Stour migrated only half-way across the Blean, and cut down to present base-level in that position. It would again expose the Lower London Tertiaries, as the diagram shows, and furthermore the east-north-east streams would have been shorter and steeper than they are in fact. They, too, would have cut down to Lower London Tertiaries, and again there would have been no continuous unit of clay. But in actuality the migration of the Stour has drawn out these tributaries for several miles. Their gradient is therefore considerably lessened: their courses lie too high to penetrate the clay-cover. Thus the process of tributary extension is intimately related to the present conformation of the Blean's surface.

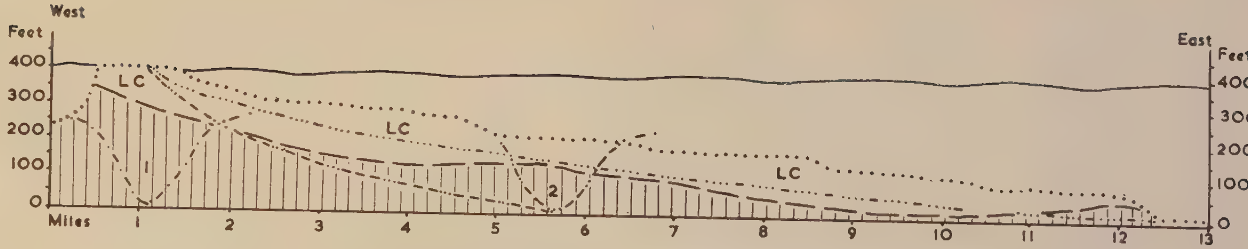


Fig. 5. Diagram to explain the preservation of the London Clay cover in the Blean

——— Initial surface at 400 ft.

— — Base of London Clay

▥ Lower London Tertiaries

· · · · · · Surface of interfluve south of Sarre Penn

— · · · · Thalweg of Sarre Penn. London Clay breached only in extreme east

– – – · · · First theoretical transverse profile of Stour Valley. In this case it is supposed that no migration occurred and the London Clay is deeply breached

—— — · · Second theoretical transverse profile of Stour Valley. Migration is fixed at half the true distance, and the clay cover is breached

— · — Theoretical longitudinal profile of Sarre Penn in the second case, steeper than at present and breaching the clay throughout almost its entire length

4. CONCLUSION

This analysis of the relief and drainage of the Blean has been based upon he evidence contained within the minor stream-valleys themselves. Its conclusion is that an orderly sequence of stream extensions and integrations occurred, and is competent to explain both of the problems which the area presents to the geomorphologist on first examination. It is quite independent of the evidence afforded by the main terraces of the parent Stour: it s, however, more fully intelligible in relation to the latter, and at the same time provides complementary testimony to the history of migration which has been traced out elsewhere.

REFERENCES

Coleman, A. 1952. Some aspects of the development of the Lower Stour, Kent. *Proc. Geol. Assoc.*, **63,** 63–86.

Dewey, H., S. W. Wooldridge, H. W. Cornes & E. E. S. Brown. 1925. The geology of the Canterbury District. *Proc. Geol. Assoc.*, **36,** 257–90.

Worsfold, F. H. 1926. An examination of the contents of the brick-earths and gravels of Tankerton Bay, Swalecliffe, Kent. *Proc. Geol. Assoc.*, **37,** 326–39.

The Annual Report of the Council of the Geologists' Association for the Year 1953

THE NUMERICAL STRENGTH of the Association on 31 December 1953, was as follows:

Honorary Members	20
Ordinary Members:	
Life Members (compounded) ...	175
Annual Subscribers	1765
	1960

During the year ninety-three new members were elected, and the Association lost 147 members through death, resignation and removals under Rule XI for failure to pay subscriptions.

Thus, the membership has suffered a net loss of fifty-four.

The list of deceased members is as follows: A. C. Ballard, Miss Grace Bigby, A. Bigot, W. N. Croft, R. E. R. Evans, C. Green, I. F. Harrison, F. N. Haward, J. Jack, J. Johnstone, F. D. Jones, E. Lawrence, Miss Mairet, E. Nuttall, W. Rivers, E. W. Skeats, L. B. Smyth, Miss Elsie White, J. N. Woodhead and A. Wrigley.

Obituary notices will be published in the PROCEEDINGS.

FINANCE

Our accounts for 1953 are presented in a simpler form than previously and it is hoped that members will therefore be encouraged to look at them carefully and so appreciate the real position of the Association financially.

On the revenue side our income from subscriptions and admission fees has increased to £1727 10*s*. 0*d*. against £1488 10*s*. 0*d*. in 1952. The arrears outstanding at the end of 1952 have realised £75 more than was expected but our arrears position is still a cause for anxiety, at £691 10*s*. 0*d*. it is even higher than at the end of 1952.

Our expenditure generally has increased although the cost of the PROCEEDINGS is slightly less than for 1952. The greater part of the item for Accountancy and Secretarial services was due to the temporary difficulty in finding a successor when Mr. Wrigley had to relinquish the treasurership owing to illness. (The anticipated cost of this item in 1954 is approximately £35.)

Owing to the increase in the price of our publications the amount received from our sales has increased although the number of sales is less.

No transfers have been made during the year from the Compounding or Illustrations Funds and no addition has been made to the Index Fund.

The Council of the Royal Society has again helped us with a grant of £250 from the Parliamentary Grant in Aid of Scientific Publications and since the close of our financial year a further supplementary grant of £50 on account of 1953 has been received.

The Association has received a most generous gift of £1000 from Dr. C. M. Heanley of Salisbury, Rhodesia, and this has been set aside for the Centenary Fund. This is the largest single gift we have had in our history and it is fitting that it should be used to mark our hundredth anniversary in four years' time.

PUBLICATIONS

Publications Committee. The Committee consisted of the seven officers and Mrs. J. M. Eyles, Dr. L. R. Cox, Mr. T. Eastwood, Dr. A. F. Hallimond, Dr. G. H. Mitchell and Dr. H. Dighton Thomas. The Committee met on six occasions and considered twenty papers on which reports were made to Council.

Proceedings. All four parts of Volume 64 were published during the year. The number of pages was 316 and there were 13 plates.

MEETINGS

Nine Ordinary Meetings were held at which four papers were read, two papers were 'taken as read', and four lectures were given.

The thanks of the Association are due to the authors and the lecturers and to the Geological Society for the use of its Apartments throughout the year.

REUNION

The Annual Reunion was held at Chelsea Polytechnic on Saturday, 7 November. Many interesting exhibits were shown and it was attended by about 300 members and friends.

Thanks are due to the Principal and staff of the Polytechnic and the members concerned.

FIELD MEETINGS

The Committee consisted of the officers (seven) and Mrs. Hawkes, Dr. W. Pitcher, Messrs. B. Ainsley, A. G. Davis, J. F. Hayward, Drs. J. F. Kirkaldy, Vernon Wilson, Messrs. D. Curry and W. E. Smith.

During the year there were three demonstrations, six whole day and four half day Field Meetings. The Easter, Whitsun and Summer Long Field Meetings were held in East Kent, Lynmouth and North Exmoor, and West Donegal respectively.

The thanks of the Association are due to the directors and all others who organised and assisted at these meetings.

THE LIBRARY

The Library Committee consisted of the President, Mrs. H. K. Hawkes, Dr. L. R. Cox, Messrs. R. V. Melville, C. D. Ovey, T. W. Marsh, R. Reeley, R. Bradshaw and J. Wilks, Librarian of University College.

The Association acknowledges with thanks the gifts of books and pamphlets listed on page 83.

Exchange of publications has been instituted with the following:

Irish Naturalists' Journal.
Annales de Paléontologie.

The exchange of publications with the following institutions has been discontinued:

Tyneside Geographical Society.
Hampshire Field Club.
Sociedad Geologica Mexicana.
Instituto Geologico del Peru.
Institutul Geologie al Romanici.
Stockholms Hogskolas.
Institut de Géologie de l'Université, Istanbul.
Ukranian Society for Cultural Relations.
Société Linéene de France.

NORTH-EAST LANCASHIRE GROUP

Chairman: J. Ranson, A.M.I.M.E., F.G.S.
Secretary: D. H. Learoyd, B.SC., F.G.S.
Committee: Mrs. Harrop, G. F. Urry, J. E. Carter, S. Westhead.

During the year five meetings were held and there were four field meetings. Particulars are published in the Report of the Session. Thanks are due to the Authorities of the Blackburn Technical College for the use of rooms.

MIDLAND GROUP

Chairman: A. J. Aiers.
Secretary: Miss Grace M. Bauer.
Committee: G. Cotton, E. D. Lacy, H. Sanders, N. Howell, I. Strachan.

During the year six meetings were held in the Geology Department, The University, Birmingham, and there were four field meetings. Particulars are published in the Report of the Session. Thanks are due to Professor Shotton for the use of the Geology Department at the University for meetings.

NORTH STAFFORDSHIRE GROUP

Chairman: J. C. Parrack, D.SC.
Secretary: T. S. Purcell, B.SC.
Treasurer: J. T. Gleaves, B.A.
Field Secretary: J. Myers, B.SC., F.G.S., F.R.G.S.
Committee: W. J. Adams, C. S. Exley, T. S. Jones, P. S. Keeling, J. T. Wattison, F. L. Williams.

During the year seven meetings were held in addition to the Annual Conversazione and there were five field meetings. Details are published in the Report of the Session. Thanks are due to the Authorities of the Arts Centre for the use of rooms. A Research Group was inaugurated, the first two fields chosen for its activities being the Bunter Pebble Beds and the *tenuis* Zone of the Upper Coal Measures.

TRUSTEES

The Trustees of the Association are:

Managing: Mr. S. Hazzledine Warren, F.G.S., Dr. W. F. Fleet, M.SC., A.R.I.C., A.C.P. F.G.S., and Mr. E. C. Martin, O.B.E., B.SC., A.R.I.C., F.G.S.

Custodian: The Royal Bank of Scotland, Western Branch.

FOULERTON AWARD

The Foulerton Award for the year was given to Mr. R. Casey, F.G.S., in recognition of his services to Geology and the Association.

HOUSE LIST

Dr. G. W. Himus retires as President after two years' zealous application to the affairs of the Association. Mr. E. Ernest S. Brown retires as Senior Vice-President and Dr. W. Pitcher and Miss D. Wisden retire as Ordinary Members of Council; Mr. T. W. Marsh has resigned owing to pressure of business.

BALANCE SHEET AT 31 DECEMBER 1953

Statement 1

	£ s. d.	£ s. d.	£ s. d.
TRUST FUNDS AND FUNDS FOR SPECIAL PURPOSES:			
Capital			3829 10 4
Accumulated Income:			
Bequest Fund (Statement 3) ...		282 4 2	
Centenary Fund (Statement 4) ...		5 13 1	
Compounding Fund (Statement 5)		296 13 2	
Illustrations Fund (Statement 6) ...		72 11 1	
Index Fund (Statement 7)		141 2 3	
Watts Charnwood Forest Fund (Statement 8)		135 10 6	
Foulerton Award Fund (Statement 9)		26 6 1	
G. W. Young Geological Investigation Fund (Statement 10) ...		81 6 7	
Henry Stopes Memorial Fund (Statement 11)		21 11 2	
			1062 18 1
			4892 8 5
GENERAL FUNDS:			
General Reserve:			
Balance 1 January 1953	329 0 0		
Add Post Office Interest	7 4 5		
		336 4 5	
Income and Expenditure Account:			
Balance 1 January 1953	214 16 11		
Surplus for Year (Statement 2) ...	38 18 9		
		253 15 8	
			590 0 1
			£5482 8 6

	£ s. d.	£ s. d.	£ s. d.
TRUST FUNDS AND FUNDS FOR SPECIAL PURPOSES:			
Investments (Statement 12)			3829 10 4
Income Tax Recoverable		10 7 4	
Cash at Bank and Post Office		1052 10 9	
			1062 18 1
			4892 8 5
GENERAL FUNDS:			
Subscriptions in Arrears		230 0 0	
Admission Fees in Arrears		3 10 0	
Cash at Bank, Post Office, and in hand		704 3 6	
		937 13 6	
Less Subscriptions in Advance	102 11 0		
Less Accrued Expenses	245 2 5		
		347 13 5	
			590 0 1
			£5482 8 6

Income and Expenditure Account for the Year Ended 31 December 1953

Statement 2

EXPENDITURE

	£	s.	d.	£	s.	d.
Proceedings OF THE ASSOCIATION				1388	5	8
GENERAL EXPENSES:						
Accountancy and Secretarial Services	105	0	0			
Addressing and Stock-keeping	31	16	0			
Field Meetings Expenses	12	2	10			
Insurance	2	2	2			
Meetings Expenses	56	7	2			
Postages	196	6	10			
Printing and Stationery	153	12	0			
Printing Monthly Circulars	232	5	3			
Sundries	9	0	2			
				798	12	5
				2186	18	1
SURPLUS FOR YEAR—per Balance Sheet				38	18	9
				£2225	16	10

INCOME

	£	s.	d.	£	s.	d.
ANNUAL SUBSCRIPTIONS RECEIVABLE:						
Received for 1953	1383	0	0			
Received for previous years	275	0	0			
Add Arrears at 31 December 1953 £691 10 0 Estimated to realise	230	0	0			
	1888	0	0			
Less Arrears at 31 December 1952 £554 10 0 Estimated to realise	200	0	0			
				1688	0	0
ADMISSION FEES RECEIVABLE:						
Received for 1953	37	0	0			
Received for previous years	4	0	0			
Add Arrears at 31 December 1953	3	10	0			
	44	10	0			
Less Arrears at 31 December 1952 £8 Estimated to realise	5	0	0			
				39	10	0
ROYAL SOCIETY GRANT				250	0	0
PUBLICATIONS SALES				248	6	10
				£2225	16	10

FUNDS FOR SPECIAL PURPOSES

BEQUESTS FUND

Statement 3

	£	s.	d.		£	s.	d.
Balance, 31 December 1953 (per Balance Sheet)	282	4	2	Balance 1 January 1953	260	7	8
				Investment Income (Statement 12)	21	16	6
	£282	4	2		£282	4	2

CENTENARY FUND

Statement 4

	£	s.	d.		£	s.	d.
Balance, 31 December 1953 (per Balance Sheet)	5	13	1	Investment Income (Statement 12)	5	13	1
	£5	13	1		£5	13	1

COMPOUNDING FUND

Statement 5

	£	s.	d.		£	s.	d.
Balance, 31 December 1953 (per Balance Sheet)	296	13	2	Balance, 1 January 1953	209	4	0
				Investment Income (Statement 12)	51	9	2
				Composition Fees	36	0	0
	£296	13	2		£296	13	2

FUNDS FOR SPECIAL PURPOSES (*Continued*)

ILLUSTRATIONS FUND

Statement 6

	£	s.	d.		£	s.	d.
Balance, 31 December 1953 (per Balance Sheet)	72	11	1	Balance, 1 January 1953	27	17	1
				Investment Income (Statement 12)		12	6
				Donation and Subscriptions	44	1	6
	£72	11	1		£72	11	1

INDEX FUND

Statement 7

	£	s.	d.		£	s.	d.
Balance, 31 December 1953 (per Balance Sheet)	141	2	3	Balance, 1 January 1953	141	2	3
	£141	2	3		£141	2	3

WATTS CHARNWOOD FOREST FUND

Statement 8

	£	s.	d.		£	s.	d.
Balance, 31 December 1953 (per Balance Sheet)	135	10	6	Balance, 1 January 1953	127	4	6
				Sales of Books	8	6	0
	£135	10	6		£135	10	6

TRUST FUNDS

FOULERTON AWARD FUND

Statement 9

	£	s.	d.		£	s.	d.
Award to Mr. R. Casey	10	0	0	Balance, 1 January 1953	23	6	7
Balance, 31 December 1953 (per Balance Sheet)	26	6	1	Investment Income (Statement 12)	10	9	8
				Income Tax Recovered 1952/53	2	9	10
	£36	6	1		£36	6	1

G. W. YOUNG GEOLOGICAL INVESTIGATION FUND

Statement 10

	£	s.	d.			£	s.	d.
Income Tax Repaid to Public Trustee	3	15	10	Balance, 1 January 1953		57	10	9
Balance, 31 December 1953 (per Balance Sheet)	81	6	7	Income (Gross) from Public Trustee:				
				Year 1952	13 15 10			
				Year 1953	13 15 10			
						27	11	
	£85	2	5			£85	2	5

HENRY STOPES MEMORIAL FUND

Statement 11

	£	s.	d.		£	s.	d.
Balance, 31 December 1953 (per Balance Sheet)	21	11	2	Balance, 1 January 1953	11	13	10
				Income Tax Repayment 1952/53	1	17	10
				Investment Income (Statement 12)	7	19	6
	£21	11	2		£21	11	2

SCHEDULE OF INVESTMENTS — 31 DECEMBER 1953

	AT COST OR VALUE WHEN ACQUIRED						INVESTMENT INCOME (GROSS)					
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
UNDS FOR SPECIAL PURPOSES:												
Bequest Fund:												
£143 8 9 3½% War Stock	141	14	0				5	0	6			
£150 New Zealand 3½% Stock 1960/64	122	5	0				5	5	0			
£285 3% Defence Bonds	285	0	0				8	11	0			
£100 3% Savings Bonds 1960/70 ...	100	0	0				3	0	0			
				648	19	0				21	16	6
Centenary Fund:												
£1000 3½% Defence Bonds				1000	0	0				5	13	1
Compounding Fund:												
£1217 2 6 Nottingham Corporation 3% Irredeemable Stock	1152	13	2				36	10	2			
£200 3% Savings Bonds 1955/65 ...	200	0	0				6	0	0			
£170 3½% War Stock	152	14	5				5	19	0			
£100 3% Savings Bonds 1965/75 ...	100	0	0				3	0	0			
				1605	7	7				51	9	2
Illustrations Fund:												
£21 0 10 Metropolitan Water Board 3% "B" Stock				20	0	0				0	12	6
TRUST FUNDS:												
Foulerton Award Fund:												
£349 7 0 3% British Transport Guaranteed Stock 1978/88				294	11	0				10	9	8
Henry Stopes Memorial Fund:												
£265 19 2 Government of Newfoundland 3% Stock 1943/63				260	12	9				7	19	6
TOTAL INVESTMENTS per Balance Sheet				£3829	10	4						

MARTIN, FARLOW & CO., *Incorporated Accountants.*

We have compared these Statements with the books and records presented to us and find them to agree.

We have also verified the Investments and Cash Balances held by the Association at 31 December 1953.

L. J. PITT, *Treasurer.*

GILBERT WILSON } *Auditors*
D. V. AGER }

REPORT OF THE SESSION 1953

Ordinary Meeting, 9 *January* 1953. G. W. Himus, Ph.D., F.G.S., President, in the chair.

E. Berrer, Miss Patricia Eileen Bowring, Miss Anthea Endora Chave Cox, Herbert Drummond Ellis, George Richard Peter Lawrence, B.SC., F.R.G.S., Lt.-Col. Francis Crofton Molesworth, R.E., F.R.A.S., Clifford David Ollier, James Thomas O'Brien Perry and Martin Lewis Thomas were elected members of the Association.

Messrs. R. Bradshaw and G. Wilson were elected Auditors of the accounts for 1952.

The following paper was read: 'Coastal evolution in Sandwich Bay', by A. H. W. Robinson & R. L. Cloet, B.A., F.R.G.S.

There was also an exhibition of a new Upper Triassic land vertebrate fauna from Bonvilston, Glamorgan, by K. A. Kermack, B.SC., Ph.D., and Miss Pamela L. Robinson, B.SC.

Ordinary Meeting, 6 *February* 1953. G. W. Himus, Ph.D., F.G.S., President, in the chair.

John Bodemead, Richard Cave, Joseph S. H. Collins, Raymond Wilbert Lindfield Goodwin, William Anthony Gordon, Mya Han, B.SC., Leonard James Hobbs, Zamir Hyder Jafri, Trevor Sudlow Jones, Frank Lovell and David Rees Morgan were elected members of the Association.

The following lecture was delivered: 'Geological work in north-east Greenland 1950–2' by J. W. Cowie.

Annual General Meeting, 6 *March* 1953. G. W. Himus, Ph.D., F.G.S., President, in the chair.

The Annual Report of the Council (already circulated) was taken as read. It was moved by Miss Mary Johnston, seconded by Mr. D. Curry, 'That the Report of the Council, including the Statement of Accounts, be adopted as the Annual Report of the Association for 1952'. The resolution was carried *nem. con.*

The President declared the following members duly elected as Officers and Members of the Council in accordance with Rule XIII: *President,* G. W. Himus, Ph.D. F.G.S.; *Vice-Presidents,* E. Ernest S. Brown, M.B.E., F.G.S., D. Williams, M.SC., Ph.D., B.E., F.G.S., A. J. Butler, O.B.E., M.SC., F.G.S., T. Eastwood, A.R.C.S., M.I.M.M., F.G.S., L. R. Cox, M.A., SC.D., F.R.S., F.G.S.; *Treasurer,* S. Bracewell, B.SC., D.I.C., A.R.C.S., F.G.S.; *Secretaries,* General—R. Reeley, F.G.S.; Field Meetings—S. W. Hester, F.G.S.; Publications Committee—W. E. Swinton, B.SC., Ph.D., F.G.S., F.M.A.; *Editor,* C. D. Ovey, M.A., B.SC., F.G.S., F.R.Met.S.; *Librarian,* R. Bradshaw, B.SC., F.G.S.; *Twelve other Members of Council,* B. Ainsley, F.G.S., Mrs. H. K.

Hawkes, M.SC., F.G.S., W. S. Pitcher, B.SC., Ph.D., F.G.S., H. Dighton Thomas, M.A., Ph.D., F.G.S., Miss D. E. Wisden, M.SC., F.G.S., A. F. Hallimond, M.A., SC.D., F.G.S., L. J. Pitt, F.G.S., Mrs. V. A. Eyles, B.SC., F.G.S., E. C. Martin, O.B.E., B.SC., A.R.I.C., F.G.S., W. E. Smith, M.SC., F.G.S., D. Curry, M.A., F.G.S., T. W. Marsh, B.SC., F.G.S., A.M.I.C.E.

It was moved by Dr. R. W. Pocock, seconded by Mr. R. S. Collins, and duly carried, 'That the best thanks of the Association be given to the Officers, the retiring members of Council, and the Auditors'.

On the nomination of the Council, Dr. W. F. Fleet, Ph.D., M.SC., A.R.I.C., was elected an Honorary Member of the Association.

The Foulerton Award was presented to Mr. R. Casey in recognition of services rendered to Geology. The President said:

> Raymond Casey: You are a native of Folkestone, and it is, therefore, not surprising that at an early age you started to collect fossils. Now, while the collecting of fossils is, in itself, a harmless pursuit, it may easily develop into an insidious desire for mere acquisition, until the addict becomes a human jackdaw, intent on no more than amassing a large collection. Fortunately, you proved immune to collector's mania, and for this, I am inclined to assign some weight to pre-natal influences in that you first saw the light actually *on* the *mammillatum* Zone, with which you have had to deal so much during your subsequent career. Something also must be attributed to the influence of Dr. Spath, with whom you first came in contact at a Field Meeting of this Association at Folkestone in 1935.
>
> As a result of this and subsequent meetings, you supplied Dr. Spath with material which was used in the preparation of the Monograph of Gault Ammonites, and you were led to make systematic searches for ammonites in the Folkestone Beds of the Lower Greensand.
>
> In the course of your researches, you have collected about 300 species of fossils from these rather unpromising deposits. You have discovered many new genera, and have also recorded forms previously unknown in this country.
>
> Although much of the information remains unpublished, you have exhibited the specimens at various reunions of the Association.
>
> Your palaeontological investigations have been accompanied by an intensive study of the relationship between the Gault and Folkestone Beds in the Weald, and you have found that although lithologically distinct, the relation between the two formations is diachronous, and that passage from Folkestone Sands to Gault may be only the expression of a lateral change of facies along the outcrop.
>
> In addition to your studies of the ammonite faunas of the Gault and Lower Greensand, you have found time to make a detailed study of some genera and sub-genera of Mesozoic lamellibranchs, belonging to the families Cyprinidae and Veneridae, with special reference to the hinge-structures.
>
> You joined the Geologists' Association in 1937, and almost immediately became a member of the Weald Research Committee, on which you have been very active. A number of papers describing your researches have been published in our PROCEEDINGS, and you have demonstrated the stratigraphical results at three Field Meetings.
>
> You have the inestimable advantage of being still a young man. The

> Foulerton Award is being made to you not merely in recognition of the work you have already accomplished, valuable though it is, but as an incentive to urge you to continue your researches. In the name of the Council and of our Members generally, I wish you 'good hunting, little brother!'

The President then delivered his address entitled 'Kerogen Rocks and Kerogen'.

It was moved by Mr. R. S. Goodfellow, seconded by Mr. J. A. Dell, and duly carried, 'That the best thanks of the Association be accorded the President for his Address'.

Ordinary Meeting, 6 *March* 1953. G. W. Himus, Ph.D., F.G.S., President, in the chair.

Orlando H. Chapman, Anthony Paul Dady, Richard Ernest Elliott, Henry Richard George, Brian Arthur Hains, F. Kim Johnson, Roger John Rice, Miss Joyce Catherine Frances Staples, Mrs. Charlotte Babette Welch and Miss Eileen Westcott were elected members of the Association.

Ordinary Meeting, 10 *April* 1953. G. W. Himus, Ph.D., F.G.S., President, in the chair.

Edgar Alfred Francis Bowden, Rev. Peter Brennan, Miss Jean Mary Clark, Alan Roy Drysdall, A. G. Fletcher, Miss Jean McKane, Miss Marjorie Winifred Reed, Hugh R. Thompson, Edward Arthur Watkin and Miss Hazell Patricia Wilkinson were elected Members of the Association.

The following lecture was delivered: 'Some recent geological observations in NW. Sutherland on (1) The Torridonian unconformity at Stoer and (2) The Durness limestone succession at Durness', by Vernon Wilson, Ph.D., M.Sc., F.G.S.

Ordinary Meeting, 1 *May* 1953. G. W. Himus, Ph.D., F.G.S., President, in the chair.

Miss Elinor May Clinch, Victor Hale, R. A. Milbourne, Michael John Rickard and Leslie Montague Young were elected Members of the Association.

The following paper was read: 'Mullion and Rodding structures in the Moine Series of Scotland', by Gilbert Wilson, Ph.D., M.Sc., D.I.C., F.G.S.

Ordinary Meeting, 5 *June* 1953. G. W. Himus, Ph.D., F.G.S., President, in the chair.

Frederick Munro Broadhurst, Raymond Thomas Cannon, Cyril George Dixon, Colin Stewart Exley, M.A., F.G.S., Hugh C. Ivimey-Cook, Philip Stanley Keeling, B.Sc., A.R.S.M., F.G.S., Ian David Procter and Miss Anne Stodgell were elected Members of the Association.

The following paper was read: 'The Rosses Granite Ring Complex, Co. Donegal, Ireland', by W. S. Pitcher, Ph.D., D.I.C., F.G.S.

Ordinary Meeting, 3 *July* 1953. G. W. Himus, Ph.D., F.G.S., President, in the chair.

John Michael Bisson, David Stewart Carmichael, Miss Ivy F. Fitchett, Ian Lindsay Freeman, B.SC., F.G.S., Miss Julia Margaret Laptain, Miss Hazel Mary Pike and George Henry Thomas were elected Members of the Association.

The following paper was read: 'The Lower Greensand in East Kent', by G. A. Worrall, M.A., B.SC.

There was also a lecture entitled: 'An outline of the geology of British Honduras', by C. G. Dixon.

The following papers were read in title: (a) 'Erosion surfaces around Dieppe', by B. W. Sparks, M.A., F.G.S.; (b) 'Glacial chronology of the Middle Trent Valley', by K. M. Clayton.

Ordinary Meeting, 7 *November* 1953. G. W. Himus, Ph.D., F.G.S., President, in the chair.

Neil Bliss, Bryan Leslie Eccleston, John Vord Hepworth and George Patrick Leonard Walker were elected Members of the Association.

The Reunion, which followed, was held in the Large Hall, Chelsea Polytechnic. For list of exhibits, see below (p. 78).

Ordinary Meeting, 4 *December* 1953. G. W. Himus, Ph.D., F.G.S., President, in the chair.

Mrs. Winifred Betty Askew, John Howard Bassett, Miss Helen Thorburn Brash, James Percy Tufnell Burchell, M.C., F.S.A., Kenneth Harold Cannell, Robin Walter Clark, Ronald Coates, P. Cupitt, William Thornton Dean, B.SC., F.G.S., Stanley Francis Denyer, Walter W. J. Etheridge, Thomas Henry Gardner, Hugh Quinton Golder, Frederick George Goodwin, John Griffith, Ronald Hopkinson, B.SC., Miss Mary Winifred Johnston, John Howard Kaser, William Alan Hartburn Keenlyside, Tatsuro Matsumoto, Eric Robin Michaelis, Edwin Alfred Archibald Nelmes, Jocelyn Pereira, Ronald Algernon George Savigear, Ronald John Small, Ian Desmond Storey, James Stuart, Peter John Wakeman and J. F. Wyley were elected Members of the Association.

The following lecture was given: 'The interpretation and significance of frost structures in Tertiary-Quarternary stratigraphy', by G. A. Kellaway, B.SC., F.G.S.

LIST OF EXHIBITS

British Museum (Natural History), Department of Geology

(*a*) Rocks, fossils and implements from Southern Africa.
  1. Australopithecine breccias.
  2. Culture of Palaeolithic Man in South Africa and Rhodesia.
(*b*) Coelacanths through the ages.
(*c*) Upper Cretaceous and Eocene fruits from Egypt and their relationship with the London Clay.

Geological Survey and Museum

(*a*) Specimens and diagrams illustrative of the geology of the Cambridge (1952–3) Borehole.
  (Jointly with the Woodwardian Professor of Geology, Cambridge.)
(*b*) Fossils from recent boreholes in Lancashire illustrating new Coal Measures marker-horizons and the 'zone of oxidation' beneath the Permian.
(*c*) Specimens from the Flin Flon Mine, Manitoba.
(*d*) Pseudomorphs from the Museum Collections.
(*e*) Colour photographs of the Museum.
(*f*) Recent publications.

Chelsea Polytechnic, Department of Geology

Exhibit of recent work by members of the Department.

Barringer, A. A.

A Servo-operated counting stage for pattern sampling and continuous line sampling under the microscope.

Best, C.

Some Foraminifera from the Oxford Clay at Woodham, Buckinghamshire.

Bishop, A. C.

Some marginal phenomena of the north-west and south-east granites of Jersey.

Bottley, E. P.

(*a*) Minerals and rocks from an excursion to Sicily and the Lipari Islands.
(*b*) An improved petrological microscope.
(*c*) New fossil casts of *Saccocoma*, etc.

Curry, D.

Lower Eocene fossils from the Tuilerie de Gan, Basses Pyrenées, France.

Dollar, A. J., Fitch, F. J. and Bassett, J. H.

A modern method of modal rock analysis.

Elwell, R. W. D.

Linear structures from the Dalradian of Mayo, Ireland.

Gunner, A.

Tufa from the Chalk Escarpment, Duncton, West Sussex.

Hallimond, A. F.

Polarising microscope with slotted eyepiece and substage lamp without transformer. For students and general use and for the universal stage.

Hayward, J. F.

Holocene sub-fossils from the Lea Valley.

Heanley, C. M.

Specimens of Beryl from Southern Rhodesia.

Johnston, Miss Mary S.

Albums of Association's photographic groups and members' signatures.

Laming, D. J. C.

Some features of the South Devon New Red Sandstone.

Marston, A. T.

Clactonian flakes from the Chalky Coombe Rock, Ricksons Farm Pit, Swanscombe.

Pocock, R. W.

Stokesay Castle, Shropshire. Watercolour painting by Howard Gaye, 1887.

Rhodes, J. E. Wynfield

Photographs of subjects of geological interest.

Venables, E. M. and H. E. Taylor

One hundred new fossil beetles from the London Clay of Bognor Regis, and other associated fossils.

Whitten, D. G. A., E. T. Raine and Students of Kingston Technical College

Minerals and rocks collected on the Third Summer Field Camp.

Wright, C. W. and E. V.
Some recent acquisitions.

FIELD MEETINGS 1953

The following field meetings and demonstrations took place:

17 *January*. A demonstration was held at the Horniman Museum.

3–6 *April*. The Easter Field Meeting was held in East Kent where Professor S. W. Wooldridge, Miss A. Coleman and R. Casey demonstrated the geology of the Cretaceous, Tertiary and superficial deposits; a visit was also made to Chislet Colliery.

25 *April*. By kind permission of the Director, Dr. F. M. Lea, a demonstration was held at the Building Research Station.

9 *May*. The Lower Greensand of the Godalming–Hindhead area was studied under the direction of J. F. Kirkaldy and F. A. Middlemiss.

16 *May*. By kind permission of the Director, Sir William Ogg, a demonstration was held at the Rothamsted Experimental Station.

22–7 *May*. The Whitsun Field Meeting was held in North Devon where the geology and morphology of Lynmouth and North Exmoor were studied under the joint leadership of Scott Simpson and C. Kidson.

31 *May*. The cliff section at Whitecliff Bay, Isle of Wight, was examined under the direction of R. Curry.

7 *June*. The Clandon and Albury district of Surrey was visited under the leadership of W. E. Smith.

20 *June*. A. G. Davis and J. E. Carrick led an excursion to Keston, Downe and the Darwin Memorial Rooms at Downe House.

4 *July*. The basal beds of the Gault were studied under the leadership of R. Casey.

19 *July*. J. F. Hayward directed an excursion to Grays, Essex.

15 *August*. The Maidstone district was visited under the leadership of W. E. Swinton, assisted by B. C. Worssam and N. Cook.

29 *August*. The Quaternary deposits near Staines were studied under the direction of Miss M. M. Howard, A. G. Davis and J. N. Carreck.

9–25 *September*. The Summer Field Meeting was held in north-west Ireland under the directorship of Dr. W. S. Pitcher, assisted by M. K. Akaad, Professor J. G. C. Anderson, R. L. Cheesman, Professor T. N. George, G. G. Lemon, D. H. Oswald, Professor R. M. Shackleton and E. H. T. Whitten.

13 *September*. P. Evans directed an excursion to the Vale of St. Albans.

4 *October*. The Lower Cretaceous rocks of Leighton Buzzard were studied under the guidance of C. W. Wright.

5 *December*. By invitation of the Anglo-Iranian and Burmah Oil Companies, forty-eight members attended a film show at Britannic House, Finsbury Circus, E.C.2.

NORTH-EAST LANCASHIRE GROUP

The following meetings and field meetings were held:

6 *February*. Lecture: 'The geology of Upper Ribblesdale', by S. Westhead.

20 *March*. Lecture: 'The scenery and geology of the Lake District', by J. Ranson, A.M.I.Min.E., F.G.S.

2 *May*. Field Meeting: 'The Grit Succession on Darwen Moors', led by D. H. Learoyd, B.SC., F.G.S.

13 *June*. Field Meeting: 'Cheesden glacial overflow channels', led by J. Ranson, A.M.I.Min.E., F.G.S.

22 *August*. Field Meeting: 'The Pennine Anticline', led by I. A. Williamson.

26 *September*. Field Meeting: 'The Sabden Shales and the Permo-Trias unconformity', led by D. H. Learoyd, B.SC., F.G.S.

23 *October*. Annual General Meeting with symposium of résumés on the Field Meetings.

27 *November*. Lecture: 'The geology of the River Darwen', by D. H. Learoyd, B.SC., F.G.S.

18 *December*. Lecture: 'The geology of the Central Pennines', by I. A. Williamson.

MIDLAND GROUP

The following meetings and field meetings were held:

31 *January*. Lecture: 'Some glaciological results of the Norwegian-British-Sweden Antarctic Expedition', by G. de Q. Robin, M.SC.

7 *March*. Lecture: 'The geology of Cornwall', by C. E. Leese, B.SC.

2–4 *May*. Field Meeting: Chipping Campden. Leader, A. Ludford, M.SC., F.G.S.

6 *June*. Lecture: 'Some exceptional American fossils', by Professor H. B. Whittington, Ph.D., F.G.S.

13 *June*. Field Meeting: The Lickeys. Leader, W. G. Hardie, B.SC., F.G.S.

11 *July*. Field Meeting: Dost Hill. Leader, H. Sanders.

12 *September*. Field Meeting: Abberley. Leader, P. A. Garrett, B.SC., F.G.S.

17 *October*. Lecture: 'Crystals', by A. J. Aiers.

14 *November*. Lecture: 'The International Geological Congress in Algeria and Morocco', by J. M. Edmonds, M.A., B.SC., F.G.S.

12 *December*. Exhibition of coloured slides and Christmas Party.

NORTH STAFFORDSHIRE GROUP 1953

8 *January*. J. Myers, B.SC., F.R.G.S., F.G.S.: 'John Ward, Wheelton Hind and J. T. Stobbs—Three North Staffordshire Geologists.'

12 *February*. Miss Mavis A. Butterworth, B.SC.: 'Microspores in Coal, and their stratigraphical significance.'

12 *March*. Annual General Meeting. Chairman's Address: Prof. F. W. Cope, D.SC., F.G.S.: 'The scope for geological research in the North Staffs. Area.'

23 *April*. T. S. Jones: Sound Films: 'Limestone' and 'Oil', followed by discussions.

14 *May*. Prof. W. G. Fearnsides, M.A., F.R.S., F.G.S.: 'N.C.B. explorations in Staffordshire.'

31 *May*. Field Meeting to North Cotswolds: Directors, D. O. Thomas and J. Myers, B.SC., F.R.G.S., F.G.S.

27 *June*. Field Meeting to Alabaster Mine, Fauld: Director, J. Myers, B.SC., F.R.G.S., F.G.S.

12 *July*. Field Meeting to Shelve District: Director, J. T. Wattison, F.G.S.

26 *September*. Field Meeting, Research Group: Bunter Pebble Beds of Trentham. Director, P. S. Keeling, B.SC., F.G.S., F.R.I.C., A.R.S.M.

15 *October*. Annual Conversazione: Exhibition of slides of Photographic Records in Geology by the Chairman, J. C. Parrack, B.SC. Exhibits of specimens, etc., by J. T. Wattison, J. Myers, D. O. Thomas, T. S. Jones, E. A. Watkin, B. Bentley and P. S. Keeling.

17 *October*. Field Meeting to Goldsitch Moss. Director, Prof. F. W. Cope, D.SC., F.G.S.

12 *November*. Prof. F. W. Shotton: 'Geology and geologists in World War II.'

10 *December*. Members' Evening: Exchange of specimens.

Omitted from 1952 *Report:*

13 *July* 1952. Field Meeting to Shineton, Cherne's Dingle and Maddocks Hill. Director: J. T. Wattison, F.G.S.

DONATIONS TO THE LIBRARY

BILLINGS, M. P. 'Structural geology.' *London*, 1942.

BRITISH MUSEUM (Natural History). 'Guide to elephants' (recent and fossil) . . . . *London*, 1922.

BROUWER, H. A. 'The movements of island arcs.' *London*, 1950.

CADISCH, J. 'Geologie der schweizer Alpen.' *Basel*, 1953.

COMMITTEE OF PRIVY COUNCIL FOR AGRICULTURAL RESEARCH AND NATURE CONSERVATION. 'The Nature Conservancy.' *London*, 1950.

XIXe CONGRÈS GÉOLOGIQUE INTERNATIONAL. Monographies régionales; 'Algerie', 'Tunisie', 'Maroc', (1re-3me série). *Algiers and Rabat*, 1952; 'Listes des géologues . . .' *Algiers*, 1952; 'Atlas photographique d'Algérie.' *Algiers*, 1952; 'Symposium sur les gisements de fer du monde.' 3 tomes + atlas. *Algiers*, 1952; 'Symposium sur les séries de Gondwana.' *Algiers*, 1952.

DALTON, A. C. 'Glacial evidences of the Sheffield area.' *Arbroath*, 1953.

DAVIS, A. G. 'The Brockenhurst beds at Victoria Tilery, Brockenhurst, Hants.' *London*, 1952; 'On the geological history of some of our snails. . . .' *London*, 1953; 'William Smith's geological atlas and the later history of the plates.' *London*; *et alia*, 'Field meeting at the Stour estuary.' *London*, 1953.

DERBY, C. A. 'Studies on the paleontology of Brazil III' (selected by A. D. Gonsalves). 1952.

EYLES, V. A. 'The composition and origin of the Antrim Laterites and Bauxites problems.' *Belfast*, 1952.

FAIRBANKS, H. R. & C. P. BERKEY. 'Life and letters of R. A. F. Penrose, Jr.' *New York*, 1952.

GEIKIE, J. 'On changes of climate during the glacial epoch.' *London*, 1872.

GILLULY, J. & A. C. WATERS, *et alia*. 'Principles of geology.' *San Francisco*, 1951.

GREGORY, J. W. 'The geology of Cyrenaica.' *London*, 1911.

Griffiths, D. H. 'Remanent magnetism of varved clays from Sweden.' *London*, 1953.

Institute for Geology and Subsurface Research, Athens. 'Eresnai epitos orsktos plostos tes Hellados. . . .' *Athens*, 1952.

[1]Maps. Berggrunnskart over Norge. *Oslo*, 1953; Glacialgeologisk Kart over Norge. *Oslo*, 1953; General geological map of Shan-Tung Province. *Tsingtao*, 1939; Geological map of Ireland based on the work of the Geological Survey. *2nd edition*, 1952; Geologische Karte der Republik Österreich und der Nachbargebiete, and appendices; Geologische Speizalkarte der Republik Österreich: Linz und Efeiding; Litschau und Gmünd; Pleistocene Eolian deposits of the United States, Alaska and parts of Canada. *New York*, 1951.

Maravelakis, M. I. & C. D. Papakonstantinos. 'Edikiai meletai epites geologias les Hellados. . . .' *Athens*, 1953.

Mededeelingen van de Geologische Stichting. Serie C. I–VI. 1945–7; Nieuwe serie. Nos. 1–4, 1946–50.

Miller, A. A. 'The skin of the earth.' *London*, 1953.

Morris, M. O. Classified geological photographs. *London*, 1952.

Osborne, F. F. 'Parc des Laurentides ice cap and the Quebec Sea.' *Quebec*, 1951.

Pallister, J. W. 'Some glacial features in the neighbourhood of Ecclefechan, Dumfriesshire.' *Edinburgh*, 1952.

Peyron, D. 'Elements de préhistoire.' *Ussel*, 1914.

Pulfrey, M. W. 'Iron ores in Kenya Colony.' 1952.

Pulfrey, W. A Kenya alnoïte and associated skarns. *J.E.A. Nat. Hist. Soc.*, **22**, 1953.

Ruskin, J. 'Catalogue of a series of specimens in the British Museum (Natural History).' *Orpington*, 1884.

Searle, A. B. 'The natural history of clay.' *Cambridge*, 1912.

Shotton, F. W. 'The pleistocene deposits of the area between Coventry, Rugby and Leamington.' *London*, 1953.

'Verzeichnis der Veröffentlichungen der Geologischen Bundesanstalt.' *Vienna*, 1952.

Vetters, H. 'Erläuterungen zur Geologischen Karte von Österreich und seinen Nachbargebieten.' *Vienna*, 1947.

---

[1] Include gifts from Norges Geologiske Undersøkelse, the Geological Survey of Ireland, the British Council and the Geologists' Association of America.

Wainefford, F. H. S. 'An introduction to the geology of Antigua.' *Antigua*, 1949.

Walton, J. 'Physical gemmology.' *London*, 1952.

Wangsjo, G. 'The Downtownian and Devonian vertebrates of Spitzbergen.' IX. Text and plates. *Oslo*, 1952.

Whitehead, T. H. *et alia*. 'The Liassic ironstones.' *London*, 1952.

Williamson, I. A. 'Intraformational contorted strata in the Upper Carboniferous of the Lancashire Pennines.' *Leeds*, 1953.

Woodward, O. H. 'A review of the Broken Hill lead-silver-zinc industry.' *Melbourne*, 1952.

OBITUARY NOTICES, 1953

GRACE BIGBY died on 24 November 1953, and the Association has thereby lost a member of long-standing and one well known in the first decades of the century.

Miss Bigby took her Bachelor of Science degree from University College, London, with botany as her main subject, and commenced her career in the teaching profession. Before the 1914–18 war she was Head Science Mistress at the Mary Datchelor Girls' School, Camberwell, but resigned from that post in order to take up war-work at Woolwich Arsenal, where there was a call for her scientific attainments. After the war she did not resume full-time teaching but continued in the educational field by taking examination classes, lecturing to students and examining for the London and Northern Matriculation Examinations.

Although having specialised in botany and later in hygiene, Miss Bigby early became interested in geology and joined the Association in 1909. It will be recalled that this was ten years before the Geological Society admitted women to its fellowship and, therefore, for a long time, it was in the Association that many enthusiastic women scientists found their geological home. Miss Bigby made many friends among the members of the Association and the chief of these was William Whitaker, together with G. W. Young, W. T. Gordon and their contemporaries. For very many years she came regularly to our meetings and participated in many of the long excursions until, in later years, home ties restricted her attendances. It is remembered that she used to be particularly kind to the 'lame duck' who occasionally attended the excursions.

Retiring by nature and upbringing, perhaps few members knew Miss Bigby intimately but her very real sense of humour, coupled with her enthusiasm for the work of the Association, stimulated warm appreciation of her character. Although she suffered from poor health since 1946, her interest in the Association and its activities was maintained until the end.

E.E.S.B.

ALEXANDRE BIGOT, Correspondent of the Institute, Commander of the Legion of Honour, died 20 April 1953, in his ninetieth year, at his home, Mathieu, Calvados. For some seventy years he investigated the geology of his beloved Normandy, of which it was said that he knew every footpath. At the Sorbonne he studied under Hébert and Munier-Chalmas. His first paper (on the Cotentin) was published when he was nineteen, and at the age of twenty-six he was appointed to the Chair of Geology and Palaeontology at the University of Caen, in succession to Eugène Deslongchamps, who later became his father-in-law. A teacher of fire and enthusiasm, Bigot held the Chair for forty-three years, and for another twenty years as Doyen he directed the Faculty of Sciences. He was, perhaps, at his best in the field, and he led excursions almost to the last. It is recorded that a few years ago he had to admit defeat at the foot of a steep incline, and stopping, said: 'My friends, climb to the top and you will find the rock I first found there forty years ago; in those days I still had legs.' At this his students carried him to the top.

The range of Bigot's interests was wide and his publications number more than 300. From 1888 onwards he was *Collaborateur Principal du Service de la Carte Géologique*, and his field work in connection with this led him into problems of water-supply, agriculture, archaeology and botany. All the time he was building up and adding to the great fossil collections of the two Deslongchamps, Jarry, and others, at the University of Caen. These collections became some of the finest in their class in the world, and many features were unique, in particular the remarkable Upper Oxfordian Mollusca of Glos, so perfectly preserved that some still showed colour-patterns, and the large vertebrates described by Deslongchamps and others. Bigot knew every specimen and he showed them with justifiable pride and loving care, always eager that they should be of use to all students and specialists.

As everyone knows and deplores, in July 1944, these collections and the library of the University were totally destroyed. At the same time Bigot lost a grand-daughter in the bombardment, and his house and library in Caen were gutted by fire. These blows would have crushed many men. Although eighty years old, Bigot accepted the inevitable and threw himself into the tasks of reconstruction. His high qualities of patriotism and loyalty to France's allies are apparent in two most interesting accounts of the Liberation of Normandy which he published in 1948 and 1950. (*Le débarquement des troupes americaines à Omaha Beach* (6–13 *Juin* 1944) (1948) and *Le débarquement à Utah Beach, la prise de Cherbourg* (6–27

Juin 1944) (1950). Ch. le Tendre & Cie., 31 Boulevard Bertrand, Caen.) The same printers issued in booklet form Bigot's citations and his autobiographical reply on the occasion of his admission into the Legion of Honour, 18 February 1950.

He was elected an Honorary Member of the Association in 1938.

All who were privileged to know Bigot and to have accompanied him in the field will treasure the memory of an outstanding figure of brilliant intellect and great charm.

W.J.A.

WILLIAM NOBLE CROFT died on 10 July 1953 at the age of thirty-eight. He was educated at Stowe and Queens' College, Cambridge, afterwards studying palaeobotany under Professor W. H. Lang at Manchester University.

His career with the British Museum (Natural History), which he joined in 1939, was interrupted by three periods of service abroad. The first was during the summer of 1939 when he went to Spitsbergen with the British–Norwegian–Swedish Expedition, the British section of which was forced to make a hurried return to Britain, arriving after war had broken out. He later joined the Royal Engineers, serving in the Middle East, India and throughout the Italian campaign. From the army he was seconded to the Falkland Islands Dependencies Survey as geologist and palaeontologist in 1945, spending a year mapping in Grahamland. He returned to England in 1947 to resume his duties as palaeobotanist at the British Museum.

Croft was principally interested in the Old Red Sandstone, having long been occupied in mapping the Brecon Beacons and Black Mountains, to which area he acted as guide during the Geologists' Association Easter Field Meeting at Hereford in 1940. He completed two short papers on the stratigraphy of the area just before his death, one being in conjunction with Dr. Gwyn Thomas. But unhappily the greater part of his work, which is of major stratigraphical importance, remains unpublished. His palaeobotanical publications also reflect his interest in the Old Red Sandstone, including papers on a Lower Devonian flora from South Wales, written jointly with W. H. Lang, Devonian charophytes and an almost completed description of some blue-green algae from the Rhynie chert. Other publications include the results of work in Grahamland, published in the *Scientific Reports* of the Falkland Islands Dependencies Survey, and descriptions of palaeontological equipment and techniques of his own devising.

He was a most patient and friendly guide to the many geologists and palaeobotanists, especially from overseas, who found their way to his room in South Kensington. A meticulous worker and ingenious technician, Croft set himself the highest standards and his refusal to accept anything less is reflected in all that he did. Modest and retiring, those who were privileged to know him well will miss him as a valued colleague and friend.

H.W.B.

FREDERICK JAMES NAIRN HAWARD died in hospital at Ealingon 5 November 1953, being in his eighty-third year. He was born at Luton, Bedfordshire, in September 1871, being the son of a doctor at St. Bartholomew's Hospital and of Ealing. He served an apprenticeship with a firm of mechanical engineers, and studied electricity at the same time at Finsbury Technical College. He then spent some years in the U.S.A. on new railway construction. Returning to England he was with several engineering firms (mechanical and heavy electrical manufacture) as designer and technical representative.

He was an Associate Member of the Institute of Electrical Engineers.

He joined the Geologists' Association in 1912 and was a founder-member of the Prehistoric Society of East Anglia (as it was then titled) in 1907.

His spare-time pursuits covered a wide range of subjects, on which he brought to bear mechanical skill and a logical mind. The chief of these was prehistoric archaeology and as much geology as is inseparable from it; and his knowledge and acumen in examining the drift deposits were of an extremely high order.

His other pursuits included numismatics, Roman and British; also the study and collection of specimens connected with the historic period of flint-mining and knapping. His study of the drifts included the collection of the associated molluscan fauna and their allied recent species.

He contributed several articles to our PROCEEDINGS as well as to those of the Prehistoric Society, notably on the eolithic problem, on which his views were directly opposed to those of the Norwich and Ipswich school; also an article on the origin of the spherical flints from which the 'Cannon-shot Gravel' takes its name.

Always ready to impart his knowledge to beginners and learners, the writer is indebted to him for much help, especially in the one small piece of prehistoric excavation that the writer performed.

The latter years of his life were clouded over by the loss of his only son in the 1939–45 war and of his wife soon after. But he carried on despite the handicap of the almost complete loss of the use of one eye and one arm (the latter the result of an accident in 1929) until overtaken by the affliction which rendered him an invalid for the last two or three years of his life.

In his more active days he was an indefatigable cyclist, travelling in this way all over the Eastern Counties, especially the Breckland area, where he did much of his collecting; and where the author of this brief appreciation of his activities often met him.

He had a large collection of specimens, all localised, as well as a library of books on his favourite subjects. Some important sections of his collections he disposed of during the last few years of his life. The very considerable remainder has been placed, in accordance with his wishes, with national and local museums and teaching establishments. The British Museum (Natural History) has taken charge of his catalogues, so that anyone with specimens bearing his markings or label will be able to trace the location and history.

H.D.H.

ERNEST NUTTALL died at the age of sixty-six, thus depriving our Association of a worthy member of many years' standing and one of the little group of enthusiasts who founded the North-East Lancashire Group.

He was born at Goodshaw in the Rossendale Hills amongst a sturdy population whose endurance matches their environment; a people who respect education and will go to much trouble to acquire it. At the age of twelve, Nuttall went down the mine, in which respect he did neither better nor worse than the bulk of Rossendale youth of his day.

One who is engulfed in strata cannot fail to garner some geology and when the mind is willingly receptive, the harvest is illimitable. It was under the Rossendale Hills that Nuttall learned the rudiments of earth science; it was as a participant of the highly creditable adult education schemes of the Lancashire boroughs that he amplified his knowledge and put his learning into perspective. As a young man he walked through the dark winter evenings along the moorland road to the outskirts of Burnley and thence by tram to evening classes. Home again on foot to study, sleep and work again by 6 a.m. the following day, constituted a nightly programme which might well daunt the youngster of today, but not the men of Nuttall's stamp in Nuttall's day. Success came in terms of certificates from the Board of Education and, eventually, as an Assistant Colliery Manager's 'ticket', but never in material progress.

He was outspoken and forsook advancement to retain intellectual integrity and he maintained dignity in face of adversity. As a geologist his chief contributions were as a collector and a 'recruiting officer' for the science. His harvest of the magnificent goniatites from the roof of the Union Mine at Bank Hall Colliery, Burnley, found their way either directly or indirectly into collections of specialists and institutions all over the world. He introduced many young men to geology and their success gave him great pleasure. In later life he struggled with illness under a climate which often tries the fittest, but took a lively interest in science, books and politics to the end.

He loved science and scholarship and revered their exponents. His life was hardly noticed in the wider sphere and may soon be forgotten; but it was not wasted.

F.H.

LOUIS BOUVIER SMYTH was born in Dublin of mixed Irish and Swiss parentage in 1883. He received his secondary education at Wesley College and entered Trinity College, Dublin, in 1902.

He took the natural science course in botany, geology and zoology, graduating in 1906 as Senior Moderator with first place and a large gold medal for distinguished answering. His principal subject in his degree was botany and he was appointed assistant to Professor H. H. Dixon. He remained in this post for three years, then for a year he was naturalist to the Fisheries Board of the Department of Agriculture and took part in several cruises, studying in particular the phytoplankton. In 1911 he joined the staff of the Iveagh Geological Laboratory under Professor John Joly where he spent the remainder of his career. In the same year he was married to Miss B. Farlow who survives him.

Subsequent to his appointment Smyth studied palaeontology at Oxford under Arthur Vaughan, and mineralogy and petrology with Grenville Cole at the Royal College of Science, Dublin. He became lecturer in palaeontology in 1913 and lectured in geography from 1931–4. In the latter year he succeeded Joly in the Chair of Geology. He was well fitted to take up the post, for, from a comparatively short time after his appointment as lecturer, he had taken a large share of the burden of the department, a share which increased progressively. He also did much in preserving and arranging the collection in the Iveagh Geological Museum. In his lecturing as in his written work, Smyth was clear and precise, and this characteristic was a valuable asset on committees and in the running of the department. He was secretary of the University Council and a Member of the Board of Trinity College in his latter years.

Outside the University, Smyth took part in the scientific life of his native city. He was for many years a Member of the Council of the Royal Dublin Society. He became a Member of the Royal Irish Academy in 1927 and served on the Council on several occasions. He was one of the original members of the Committee for Quaternary Research in Ireland and his advice and support were most helpful in the initial stages. He organised the South Ireland excursion of this Association which was arranged for 1939, and was responsible for the preparation of the guide which, when the excursion fell through owing to the imminence of war, was published in our PROCEEDINGS.

With few exceptions Smyth's published papers deal with the Carboniferous of Ireland, only one paper, that on the geology of Great Ormes Head, taking him outside the country.

He carried on the work of Matley and Vaughan in Co. Dublin by studies of the faunal zones of the Rush Skerries Carboniferous Series and of the coast section at Malahide. In 1930 he published in the *Proceedings of the Royal Irish Academy* a paper on the Carboniferous Rocks of Hook Head, probably his most important work, in which he was able to trace a complete succession from the Upper Old Red Sandstone to the top of the C_2 zone. Studies on particular fossils gave material for other papers; but by 1938 the increased responsibility of his department and the first signs of failing health intervened so that it was not until shortly before his death that he was in a position to publish his further work on north Co. Dublin, in two papers: 'The Carboniferous system in north County Dublin' (*Quart. Journ. Geol. Soc. Lond.*, **105**), and 'A Viséan cephalopod fauna in the Rush Slates of Co. Dublin' (*Proc. Roy. Irish Acad.*, **53,** B 15).

Smyth was quiet and retiring by nature, and a kindly and friendly man. He did not readily offer criticism, but when approached, his help was generous, and the value of his comments were enhanced by the gentleness with which they were given.

A.F.

ELSIE WHITE died in January 1953. The Association has thus lost a keen and active member who will be sadly missed by a large circle of friends. A native of Woolwich, Miss White was educated at University College, London. On taking her degree she joined the teaching profession and served under the London County Council until she reached the age for retirement a year before her death. She became specially interested in geography and was the author of a text-book, and part author of another, for use in schools. She was always kind-hearted and generous to young people, in whose welfare she took a keen interest. Miss White joined the Association in 1925 and served as Secretary for Field Meetings from 1937–43, and as a member of the Council from 1944–7. On many occasions she acted as local secretary for Field Meetings. In 1948 she received the Foulerton Award for services rendered to the Association. Apart from geography and geology, her greatest interest lay in gardening. Her collection of specimens has been accepted by Queen Mary College, London.

A.G.B.

ARTHUR GEORGE WRIGLEY was born 29 April 1885, at Hackney. His father's family was long established at Saddleworth, West Riding, Yorkshire. He received an elementary education at a local Board School, continuing with the aid of a scholarship at the East London Technical College. He abandoned an early project of becoming a Wesleyan Minister (he has preached sermons) and entered business as a shopfitter's draughtsman and continued in this occupation until his retirement in 1951.

An early interest, apart from omnivorous reading, in architectural antiquities under the influence of his cousin, George Wrigley, topographer and genealogist, took him during holidays to many parts of England and France to see churches, castles and old towns. He married his cousin, Margaret Wrigley, who respected and encouraged his interest and who now survives him.

A holiday in the Derbyshire dales and caves first aroused his interest in geology and lead him to study Woodward's 'Geology of London' and the model of it at the Geological Museum, Jermyn Street. He began collecting in the Chalk quarries, brickyards and gravel pits around London and on a walk in Kent became acquainted with Harrison of Ightham and F. J. Bennett of West Malling; the latter persuaded him to join the Geologists' Association. He became very occupied with the study and collecting of flint implements, but abandoned all further work on this subject when, in 1912, he discovered an interesting fauna from the London Clay at Chingford. With the aid of E. T. Newton, he wrote his first paper on London Clay fossils. Newton advised him to take up work on the London Clay—a study which had utterly lapsed—and he was able to follow this advice in many post-war exposures round London and in the Hampshire and Isle of Wight areas and became associated with A. G. Davis who worked at the microfaunas. Wrigley began about 1920 to study the Edwards Collection of Eocene Mollusca at the British Museum (Natural History) and was advised by Dr. F. A. Bather to publish some of its many undescribed species. He commenced to do so by publishing a paper in the *Proceedings of the Malacological Society* and has continued by writing a series of short monographic papers on Eocene Mollusca with occasional stratigraphical papers in our PROCEEDINGS. (A complete bibliography of Wrigley's work will appear in the *Proceedings of the Malacological Society*.)

Wrigley never pretended to any comprehensive knowledge of geology or Mollusca, but he tried to find out about them as he went along. He considered that drawing his own illustrations was a potent aid to study and concentrated attention to the essentials of form and structure in representing them by line and shade. He thought it was essential to combine stratigraphical geology and field collecting with descriptive palaeontology.

He combined a great insight into the structural relations of the objects he studied with a strong contempt for many modern theories which endeavour to explain these relations. His writings abound with shafts aimed at the authors of these theories. Wrigley's output is impressive and of a high standard and all the more remarkable because the whole of it was accomplished in his leisure hours.

His contributions to Eocene stratigraphy were important and space only permits reference to his study of the faunal divisions of the London Clay (*Proc. Geol. Assoc.*, **35**, pp. 245–59) and the discovery of a Cuisian fauna in the Hampshire Basin (*Proc. Geol. Assoc.*, **48,** pp. 203–25). The former is a revised classification of the London Clay and its fauna and brings up to date a study first commenced by Wetherell and Prestwich. The latter work deals with the discovery of *Nummulites planulatus* in the lowest Bracklesham Beds of Selsey and the Isle of Wight. Lyell, in 1852, had predicted that strata characterised by this nummulite may exist in our Bracklesham Beds. For three-quarters of a century this problem had engaged the attention of those concerned with English Eocene Geology until in 1935–6 he, in collaboration with the writer, carried out researches which provided a conclusive solution.

He collected widely from the Lower Tertiaries both of England and Western Europe, and exchanged materials with other collectors all over the world. In this way he amassed a large collection of Lower Tertiary fossils which he maintained in immaculate order and which was acquired, together with a large series of MS. notes, by the British Museum (Natural History) just before he died.

He was an ardent bibliophile who haunted the bookshops of Charing Cross Road and the barrows of Farringdon Street at a time when many bargains were to be had, and he accumulated a fine library.

The collection both of books and fossils was accomplished out of his very modest means, and bears eloquent testimony to the devotion with which he pursued his interests.

In personal appearance, he was tall and spare, with a slight stoop and an air of abstraction which belied his penetrating and alert mind. He read very widely and not only on geological subjects. His acquaintance with the classical authors and the philosophers of all ages was unusually great by modern standards, and he loved to coin an epigram or to point a moral. His genial and discursive disposition made him many friends, not least among the younger generation of geologists, whom he delighted to help in every way possible.

His other interests were music—especially that of Bach, Handel and Beethoven—and gardening. He received the Association's Foulerton Award in 1927 and the Wollaston Fund of the Geological Society in 1933.

For several years he was a Vice-President of our Association and also of the Société Géologique de France and probably the only Englishman to receive the latter honour in recent years. He was President of the Malacological Society of London, 1945–7.

After his retirment he worked at the British Museum (Natural History), the happiness that this brought him was cut short all too soon by illness. He passed away in his sixty-seventh year on 7 August 1953.

The writer is indebted to Mrs. A. G. Wrigley for the chronological particulars of this notice. A.G.D.

The Origin of Aplites

vith special reference to those in Jersey, Channel Islands

by A. KINGSLEY WELLS and A. CLIVE BISHOP

Received 5 June 1953; read 8 January 1954

CONTENTS

. INTRODUCTION ... page 95
. PETROLOGICAL CHARACTERS ... 95
. STRUCTURAL CONSIDERATIONS ... 104
. CHEMICAL CONSIDERATIONS ... 108
. CONCLUSION ... 109
ACKNOWLEDGMENTS ... 110
REFERENCES ... 110
DISCUSSION ... 111

BSTRACT: The structural, petrological and chemical features of aplites are discussed with special reference to the problem of their origin. Their relationships to the ountry-rocks are examined and the question is raised as to whether their mode of ormation may be deduced from a study of the structural evidence alone. The petroogical characters of several aplites are described with particular reference to the significance of such marginal phenomena as the forms of micrographic intergrowths of quartz and orthoclase. No new chemical facts are presented but the available evidence in this field is reviewed in the light of the structure and petrology of these ocks. It is concluded from the study of these features that the aplites with which the uthors are acquainted result from the crystallisation of a magma fraction rather han by the replacement of country rocks *in situ*.

---

1. INTRODUCTION

UR MAIN OBJECT in this paper is to review the facts bearing on the nature of aplites, particularly in relation to the problem of their origin. In this essentially petrogenetic problem, three lines of evidence may well be of equal importance: (1) the *petrological*, involving the facts of mineral composition and textural inter-relationships; (2) the *structural*, based on observed field-relationships; and (3) the *chemical*. In the early pages of this paper we deal with petrological matters (largely textural interpretation), making only passing reference to structural considerations. The latter are discussed subsequently in more general terms. Although we have no new chemical data to record, certain theoretical considerations are so important that they cannot be omitted, and are briefly discussed.

2. PETROLOGICAL CHARACTERS

In Jersey, aplites are abundantly exposed at many points round the coast, so that field-relations with the (presumed) parent granites and the associated more basic rocks are particularly clear. No general account is necessary, for they closely resemble aplites of other ages occurring in other areas. As is commonly the case, they prove to be late in the petrogenetic sequence, penetrating freely into the main granites with the associated more basic rocks, and more locally into the sedimentary greywacke-shale series of the island. They antedate the lamprophyres (Robinson & Mourant, 1936, p. 24) and numerous basaltic dykes, for example in the South-East Complex at Le Hocq. The general time-relations are clearly displayed on the west side of the headland at Ronez (Fig. 1).

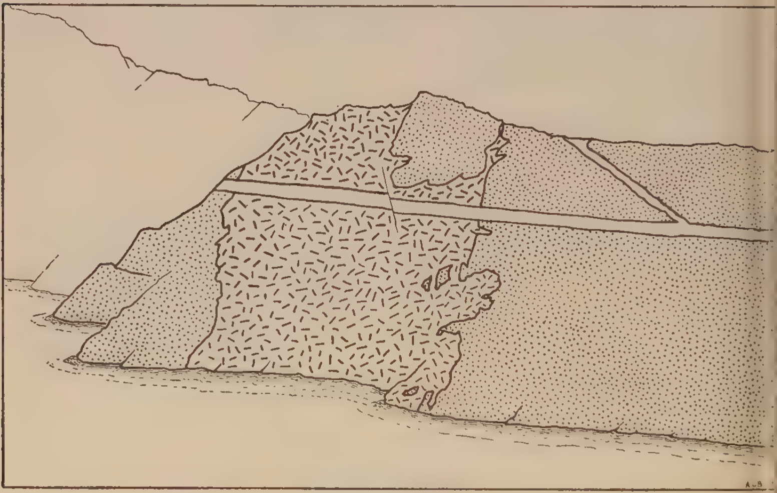
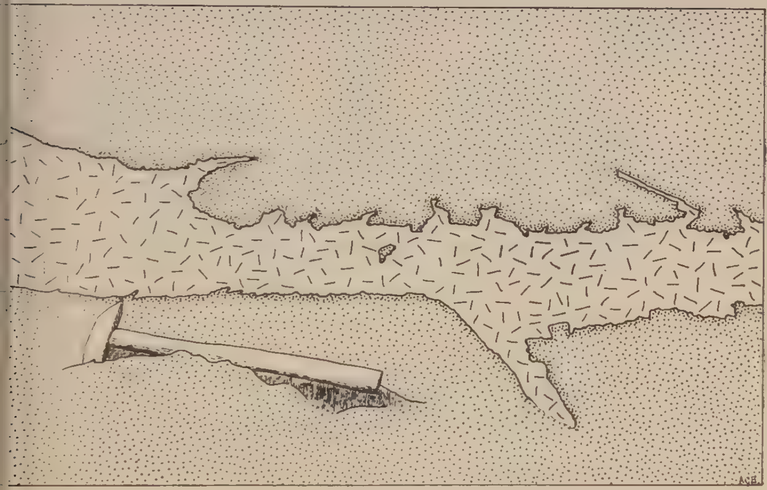


Fig. 1. Diagrammatic view of relationships at Ronez, North Jersey. The cliff is abou 30–40 ft. high.
Diorite: stippled. Granite: dashed ornament. Aplite: blank

Although exposed at many points, the aplites are particularly wel shown on the foreshore under the Battery at Ronez, at Sorel Point and at Le Fossé Vicq in the north of the island, and at Elizabeth Castle, St Helier, in the south. The latter locality is specially important in the present connection as sill-like sheets of a quite different character are available for study in adjacent exposures. These are *granite* sheets and they serve the invaluable purpose of preventing one from committing the error of believing that all sharp contacts between granitic and other rocks must necessarily be magmatic (Fig. 2). These particular granite contacts are highly irregular; the upper and lower contacts do not agree in configuration; and they are emphasised by the development of a compact dark zone, black and basaltic looking against the granite, but in an inch or so rading into the normal country rock, here of dioritic composition. It is bvious that these are replacement boundaries, and as they are so distinc-ve, they are readily recognised as such in the field.[1] They stand in direct ontrast to the boundaries of the aplites, which are almost invariably raight and knife-edge sharp. Moreover, there is no appreciable darkening f the country-rock due to the marginal concentration of coloured inerals—the miniature 'basic front'—which is characteristic of the eplacement boundaries.



ig. 2. Granite Sheet in diorite: darkened margin to the latter. Elizabeth Castle, ersey.
Diorite: stippled. Granite: dashed ornament

So far as their mineral composition is concerned, an outstanding feature f the aplites is their apparent uniformity. Although they cut indiscrimin-tely across pink aplogranite, grey porphyritic hybrid granite and dark oloured diorite—and back again—there are no corresponding variations n the mineral contents of the aplite-veins. Had they been formed by eplacement of these several rock-types *in situ*, such homogeneity would e exceedingly difficult to understand, and we regard this as strong evidence gainst a replacement origin for these rocks. Occasionally, a composite plite is encountered. Thus a three-inch vein cutting diorite at the specta-ular Le Fossé Vicq locality consists of a thin, dark red, central zone anked symmetrically by flesh-coloured aplite with a megascopic graphic texture. Probably the most striking of the composite aplites is that which i traceable for several yards from the main granite contact at Le Pulec in the north-west of the island, into the adjoining greywacke-shale group The contacts are, as usual, knife-edge sharp, and the sheet is symmetricall composite, with marginal off-white equigranular aplite flanking a centra pinkish grey porphyritic facies. This six-inch sheet shows an interesting contrast between its upper and lower margins. The latter at one point has been fractured, overthrust and buckled under; but no trace of this structure occurs at the upper margin, indicating that these features must have been produced by lateral movement when the central part of the sheet was still fluid (Fig. 3).

---

[1] A full petrographic description of these sheets would carry us beyond the scope of this paper; ut it is intended to consider them more fully in a subsequent publication.

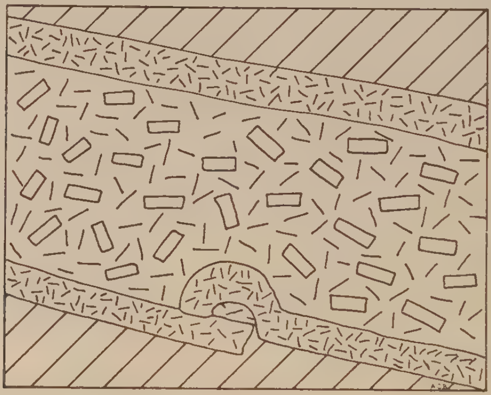
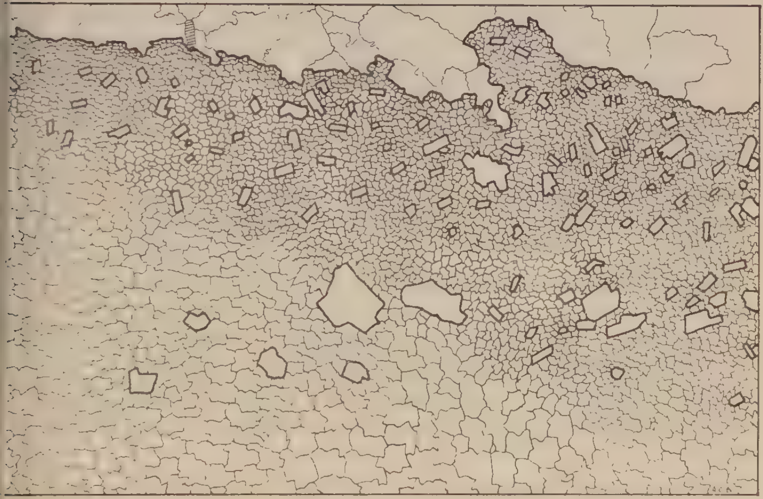


Fig. 3. Composite Aplite vein in 'Shale' series, Le Pulec, NW. Jersey.
'Shale' series: ruled. Marginal aplite: small dashes. Central, porphyritic aplite: large dashes.
The vein is 6 in. thick

Petrographically, the Jersey aplites are closely similar to the average aplite, the composition of which is well known (Johannsen, 1932, p. 92 Quartz and alkali-felspar heavily outweigh the dark minerals, the colour index averaging three only. The grain-size varies from medium to fine, sometimes even within the limits of one thin sheet. Many of the Jersey aplites conform to the standard text-book specification as regards texture, being xenomorphic granular or 'saccharoidal'; but the more interesting are those in which the alkali-felspar and quartz are intergrown. The intergrowth varies in scale: in some specimens it is just megascopic; but more frequently it is on a microscopic scale. Of the specimens studied some 30% show no intergrowth at all, 25% are dominantly graphic or micrographic, while in the remainder the micrographic is associated with th

icrogranitic, the two being frequently inter-banded. In what follows the
rm micrographic is used in a rather wide sense for that intimate associa-
on of alkali-felspar and quartz usually referred to as 'intergrown'. In some
stances the intergrowth is genuinely micrographic, as the quartz in-
uded within the felspars assumes the form of geometrically shaped
ieroglyphs', resembling runic characters, exactly as in the coarser grained
aphic granites and pegmatites. In other instances, however, the quartz
cks the characteristic geometrical shapes, the term 'vermicules' is more
ppropriate than 'hieroglyphs', and the resemblance to myrmekite is very
ose.



ig. 4. Aplite with fine-grained marginal zone containing microphenocrysts of alkali
lspar, Elizabeth Castle, South Jersey.
Drawing represents actual size of 4.5 x 2.8 mm.

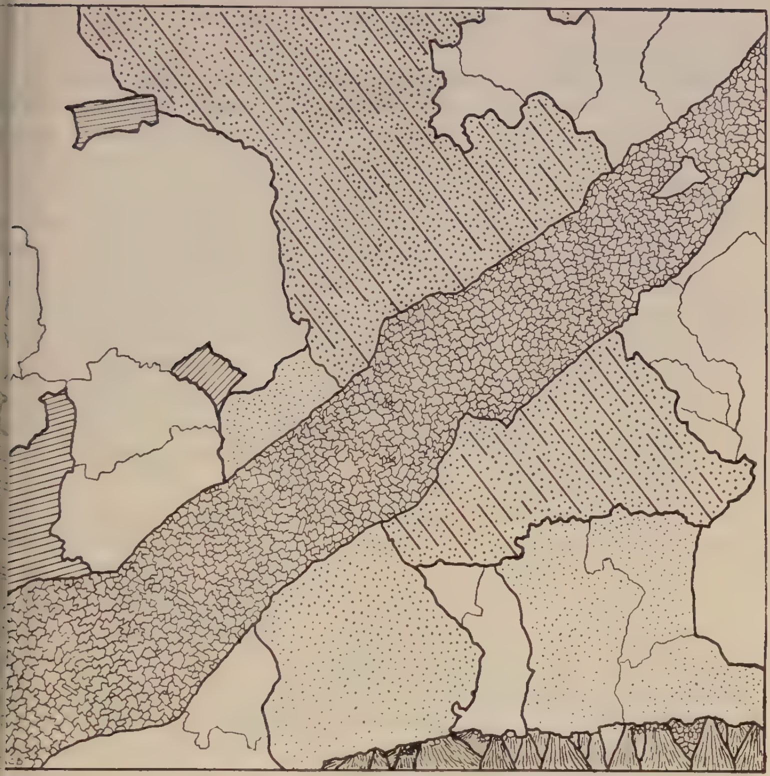
In a discussion of the structural relations of aplites and pegmatites,
. C. King (1948, p. 473) has stated that these rocks do not show chilled
argins; while G. E. Goodspeed (1940, p. 195) noted that chilled margins
re absent from dykes formed (in his opinion) by replacement. Be that as it
ay, our experience has been different from King's and, although there
re exceptions, the Jersey aplites commonly show chilled margins and this
pplies also to pegmatites in certain other areas. In the majority of speci-
ens examined there is a marked difference between the contact-phase
nd the material in the body of the aplite, though the grain-size even at
oints remote from the contact is invariably considerably less than that of
he country-rock. It may even be cryptocrystalline and charged with

euhedral microphenocrysts of alkali-felspar in the marginal phases, passing centrally into microcrystalline rock (Fig. 4). Such a texture cannot result from *in situ* replacement. This textural evidence is conclusive in itself; but it is reinforced by the complete absence of marginal darkening of the country-rock (frequently a diorite with a colour index of 50 or more), such as would necessarily arise through the dispersion of the unwanted Ca, Mg, Fe ions.

We do not claim that there has been no interaction between the melt and the country-rock. On the contrary, although the boundaries are megascopically straight, under the microscope they are seen to wander somewhat in detail, due presumably to slight selective corrosion. The mineral most affected is microperthite, in which minute granules of quartz appear, while quartz, plagioclase and coloured minerals are normally unaffected. Further, veinlets of quartz may penetrate for a short distance into the country-rock along intercrystal boundaries. The amount of corrosion and the degree of penetration by the veinlets is dependent upon the rate of cooling: for the thicker the aplite, the deeper the penetration, and the more pronounced the corrosion. Occasionally, veinlets of a different kind occur. These are of aplite and penetrate short distances into the granite or diorite bordering the main sheet. Except for their minute size, in their structural relationships they are precisely like the classical veins of teschenite which penetrate into the Carboniferous sediments beneath Salisbury Craig Edinburgh, and, like them, provide indubitable evidence of an intrusive origin (Fig. 5). Indeed the analogy can be carried farther, because the aplite veinlets, like their megascopic analogues in Edinburgh, have lifted microxenoliths from their walls and floated them into the body of the intrusion.

The most convincing evidence of crystallisation from a melt is afforded by aplites from Ronez and Grève d'Azette in Jersey, while identical evidence is displayed by a casually selected one-inch aplite vein in granodiorite from Bheinn Cruachan, sectioned for teaching purposes. In all these specimens the contact is particularly sharp, and a narrow chilled zone occurs, seldom more than a fraction of a millimetre in width. This zone is fine-grained and compact. Inwards the grain-size rapidly increases and a micrographic texture of a very special kind is developed.

Here the intergrown felspar and quartz form units which are V-shaped in plane section and presumably more or less conical in three dimensions. The cones have their apices on the inner side of the contact-zone; they stand in parallel formation, with their axes perpendicular to it. In some instances the cones are themselves composite and embrace several smaller units in sub-parallel orientation and expanding distally. To a palaeontologist the impression would be strongly conveyed of closely packed *Dictyonemas* dependent from the 'ceiling' of the vein (Fig. 6A). At other



ig. 5. Aplite cutting hybrid diorite and displacing a microxenolith (lower portion of rawing) Ronez, North Jersey.

Felspar: fine stipple. Hornblende: coarse stipple and lines indicating cleavage. ica: ruled. Quartz: blank.

On the extreme bottom right-hand edge is a micrographic intergrowth. Size of section x 6 mm.

oints along the contact the units of intergrowth are more parallel-sided nd feather-like in plane section, for the quartz-fibres diverge at approxmately 45° from the axis.

An exactly comparable texture may be produced artificially in crystalising cholesterol acetate on a glass slide. In the body of the slide, if the ate of cooling is correctly controlled, perfect, isolated spherulites are ormed; but on the edge of the preparation crystallisation commences at losely spaced centres, each of which is, in effect, a centre of spherulitic rystallisation. Naturally, the spherulites can only grow inwards, and on ccount of the close spacing of the centres, mutual interference results in the formation of wedge-shaped units precisely like those occurring in the rocks under discussion.

A further variant of this texture is displayed by an aplite from Grève d'Azette. In this rock the units of intergrowth expand inwards, forming distinctive wedges, but instead of being normal to the contact surface they are all inclined at an angle in the same direction, like trees before a prevailing wind. This must be a consequence of movement within the aplite-vein, presumably when the central portion was still fluid (Fig. 6B).

Immediately inside the marginal zone, described above, the texture changes rather abruptly: it becomes microgranitic rather than micrographic, but is liable to vary rapidly along the strike. The microgranitic texture may give place to the normal micrographic in which the intergrown units become irregular in form and completely disorientated. Further, the quartz-hieroglyphs become more typically geometrical in shape, with emphasis on triangular cross-sections. Or, again, comparatively large patches of closely sutured quartz-grains may occur in close association with grains of microperthitic felspar.

We are fully aware of a division of opinion as to the primary or secondary nature of the micrographic texture in rocks; but from their nature form and attitude, it is surely clear that the wedge-shaped units and the feathery intergrowths, both with their axes at right-angles to the margin of the aplite in which they occur, and both rooted in the contact-zone, both increasing in girth inwards, must be primary structures. It is inconceivable that replacement of alkali-felspar could operate in this way. This being so, it is equally clear that crystallisation commenced in the contact-zone and proceeded inwards—not *vice versa*, which would have to be the case if a replacement process had been operative. This, in turn, is proof of a magmatic origin.

Two analogues of these structures come to mind. The conical units with slightly divergent quartz-fibres are closely similar to segments of the large composite spherulites occurring, for example, in some of the Yellowstone Park spherulitic obsidians. In these, the direction of growth of the individual crystal-units is self-evident. Reference may appropriately be made at this point to supporting evidence afforded by a very different type of rock At Megaliggar, near Porthleven, Cornwall, a ten-foot sill of granite-pegmatite intimately associated with aplitic material is intrusive into killas.[1] There is a definite, though minutely thin, contact-zone in which the crystals in the pegmatite are rooted. Prominent among them are acicular tourmalines suspended at right-angles to the upper surface of the sill, and pinkish alkali-felspars of Baveno habit and, therefore, of approximately square cross-section. These latter steadily increase in girth down-

---

[1] This rock has been figured in Hatch, Wells & Wells, 1952, p. 205.

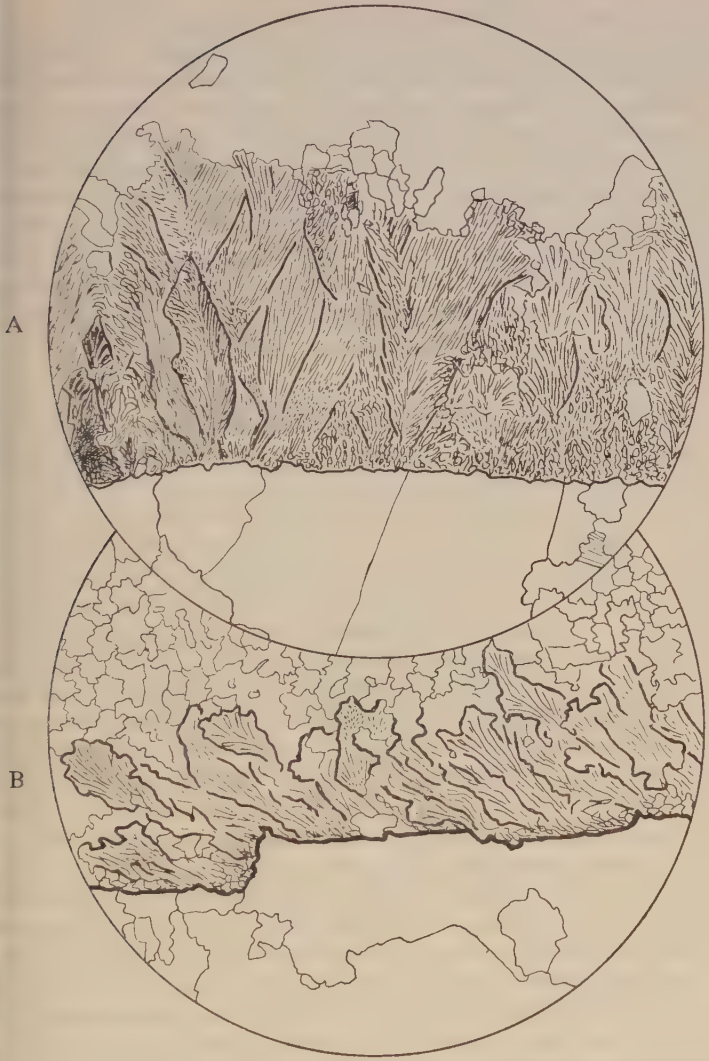


Fig. 6A (above). Radiating intergrowths of quartz and alkali-felspar growing towards centre of aplite-vein from granite wall (lower portion of drawing). Bheinn Cruachan. (Diameter of drawing 2.5 mm. approx.)

Fig. 6B (below). Intergrowths of quartz and alkali-felspar growing towards the centre of aplite-vein and away from the wall of hybrid granite (lower portion of drawing) but nclined to the left by movement in the vein. Grève d'Azette, South Jersey. (Diameter of drawing 1 mm. approx.)

wards until they ultimately reach a diameter of some two inches. They resemble acute-angled tetragonal pyramids suspended by their apices from the points in the chilled zone where crystallisation commenced. This rock affords a particularly convincing demonstration of the facts that *some* pegmatites have chilled margins, and, in these cases, crystallisation demonstrably commenced at the margins and worked inwards, indicating crystallisation from a melt. Admittedly this bears only indirectly on the main problem of the origin of aplites; but the rock, which underlies the pegmatite, is largely aplitic, and the sheets are actually composite intrusions. If the marginal pegmatite is magmatic, so must be the aplite with which it is so intimately associated.

3. STRUCTURAL CONSIDERATIONS

Certain structural features have been touched upon in the above account but, in this section of the paper, the evidence relating to the mode of formation of the aplites is examined more critically. Goodspeed (1940) first drew attention to the fact that, in some instances, a later dyke cutting obliquely across another of earlier date does not show the displacement of the outcrops ('offsetting') that might be expected if the normal method of dyke injection had operated. He therefore claimed that dykes must originate in two different ways: either by dilational injection, or by replacement. The former mode of origin involves opening a fissure by *displacement* to make room for the dyke material; while the latter involves no such movement and further, the dyke material is metasomatic—not magmatic in such cases

Before entering into details, it may be as well to state that, in our opinion, the reliance that may be placed upon such structural evidence depends largely upon the nature of the later dyke-rock. If it is basaltic or doleritic some reason other than origin by replacement must be sought to account for the apparent anomalies in the structural relationships. It is wildly improbable that any process of replacement can give rise to normal basalts and dolerites: these, at least among igneous rocks, are genuinely magmatic

With aplites, however, the case may be different. The term 'aplitisation has been used for a hypothetical process of replacement, whereby aplite has been formed from country-rock, of whatever composition. The evidence for such an origin is almost entirely structural; and the absence of offsetting is regarded as critical—indeed, the case for replacement stands or falls on this structural interpretation. The problem is, of course a three-dimensional one; but it may be reduced to two dimensions if *al* the structural features concerned are vertical. In these circumstances whether or not offsetting occurs depends upon the relationship between the strike of the earlier structure and the direction of movement by which the later fissure opened. It is often tacitly assumed that the blocks on ther side of the fissure move at right-angles to it. It may well be that in an ea traversed by a regional dyke-swarm the stress conditions are such as allow the fissures to open in the approved dilation-injection manner, nder simple tensional conditions; but in an area where the pattern of the ykes suggests a 'jig-saw' type of structure, the conditions are far less mple. Movement in relation to any one fissure is controlled by the form nd disposition of nearby 'retaining' blocks, bounded by fissures trending several different directions. The optimum condition for offsetting will e achieved only when the two blocks concerned are allowed to move at ght-angles to the fissure. If the direction of movement is parallel to the arlier structure, the offsetting effect becomes zero.

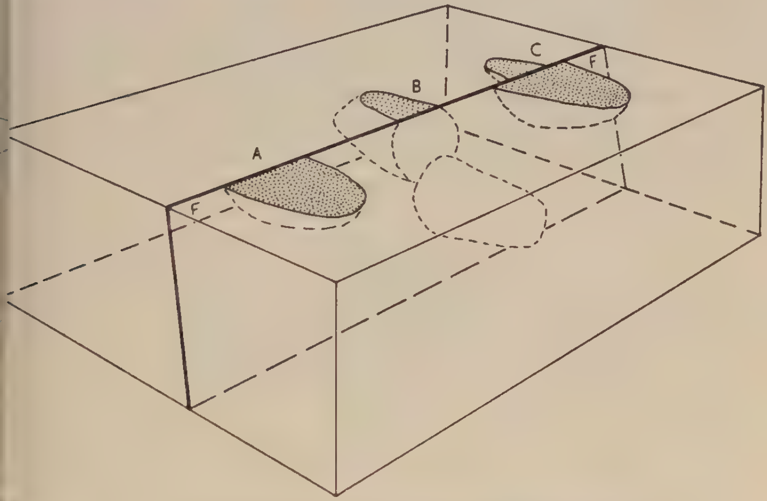


Fig. 7. Block diagram illustrating effect of faulting on xenoliths

Similarly, of course, if the earlier structure strikes at right-angles to the ater fissure, there can be no offsetting, provided the fissure and the earlier yke, or other suitable structure, are vertical. If not, offsetting must result.

Again, complications are introduced into the problem when horizontal ovement along the fissure occurs, before, during, or after injection of he later dyke. Such movement may neutralise the offsetting effect, or may everse its direction: many such cases have been figured. Now, given that orizontal movement along the feeding fissures is proved by field-observations, it seems to us that vertical movement is almost inevitable too, and he problem becomes three-dimensional. An interesting and significant ase is that of a dyke cutting across xenoliths embedded in the country-rock. It has been argued that such xenoliths *must* be represented on both sides of a dyke of normal type, intruded after dilation along a fissure; and, conversely, that, if they are represented on one side only, or if the boundaries are continuous across the dyke, the latter must be of the replacement type. In our view the relationships are controlled by the three-dimensional shape of the xenoliths and vertical movement along the dyke-fissure. To illustrate this point, three xenoliths standing at somewhat different levels in the country-rock, are shown in Fig. 7. They are traversed by a fracture along which there has been a small easterly down-throw. At ground level 'A' and 'B' are 'glancing sections' near the bottom and the top respectively of the two xenoliths. The left-hand part of 'A' has, therefore, been denuded away; while the right-hand part of 'B' is below ground-level. The xenolith 'C' would be interpreted as the bottom half of a rounded body, which therefore behaves as if it were a miniature synclinal basin cut by a dip-fault. Now if an aplite-vein is intruded along this fault the relationships are precisely like some that have been figured and quoted as proving a replacement origin for the dyke concerned; but in the absence of a complete three-dimensional picture of the occurrence the structural interpretation suggested above is at least as feasible, and in our opinion, far more likely.

Thus the absence of offsetting may be due to a variety of causes, of which replacement is one; but replacement is by no means proved by the unsupported fact that offsetting does not occur at a point where theoretically it might be expected. Admittedly there is a limit to the extent to which one can explain away the absence of offsetting. If a later dyke crosses two earlier intersecting ones without displacing either, it is difficult to find any combination of circumstances adequate to account for this relationship on purely structural grounds. An actual instance has been studied by Billings (1925, pp. 140–50), in which a massive (400 ft.) 'diabase' dyke is the central feature. According to the map which illustrates the paper, several earlier dykes striking in different directions occur on both sides of the diabase, but show no offsetting. Two points are significant. Firstly, the later dyke is of basaltic composition; and secondly, Billings did not argue from these facts that the diabase has been formed by *in situ* replacement, but explains the field relations as resulting from a special mechanism of intrusion—that of vertical block-displacement. The surface expression of this mode of intrusion would be precisely the same as if the dyke material had replaced its own bulk of country-rock.

An illustration in Sir John Flett's memoir on The Lizard and Meneage has been used to substantiate the opinion that absence of offsetting proves a replacive origin for the later dyke concerned. Unfortunately, the precise location of the spot is not indicated in the memoir, and, indeed, it is doubtful if it represents what is seen at any one spot, but indicates the relationships between the several rock-types concerned, inferred from observations made at a number of different points. During a recent brief visit to Coverack Cove with a Field Class, a search was made for the occurrence illustrated, but without success, though the rocks are extremely well exposed in wave-cut sections. One exposure in particular seems critical in connection with the present discussion. One of the thin 'black dykes', presumably basaltic, in a distance of only three yards or so, cuts across two earlier gabbroic dykes in the serpentine. In the one case there is no offsetting; but in the other the gabbro is distinctly offset by the basalt. Thus the evidence is contradictory and is unreliable as a criterion of origin, as we have claimed from theoretical considerations above.

Two other structural features are exhibited by certain aplites and pegmatites for which a replacive origin is claimed on the evidence of absence of offsetting, and which are themselves therefore regarded as providing supporting evidence in favour of the replacement hypothesis. These features are (1) the rapid wedging-out of a sheet into the country-rock; and (2) the splitting of a single sheet into a number of thinner ones.

With regard to the first, we would say only this: it is a common phenomenon not only among aplites and pegmatites, but also among intrusive basalts and dolerites. Primarily for this reason, but also because, in our experience, this is not the kind of contact resulting from replacement, we find it quite impossible to accept this as evidence of replacement. On the contrary, such wedging-out is merely the local expression of the control of the form of the intrusion by an intricate joint- or fracture-system. One of the most spectacular instances known to us is a dolerite sheet up to six feet in thickness, well exposed though difficult of access, near the foot of the red granite cliffs at Grosnez on the north coast of Jersey. At one point the sheet suddenly wedges out almost completely in a distance of a few feet only, though it reappears farther round the coast. Now unless dolerite can be formed, by replacement, from ordinary granite, such wedging-out must be regarded as a normal intrusive structural relationship. In such a setting replacement is extremely unlikely.

Secondly, the breaking up of a single aplite-sheet into a number of thinner ones maintaining the same general strike is a common feature of the Jersey aplites, one instance being figured (Fig. 8). Clearly, these aplites have been fracture-guided, and it seems to us to be self-evident that the splitting into thinner sheets is due to a single fracture giving place to a number, probably under conditions involving shearing, which in the one case shredded the country-rock into lenticles lying between the limiting fractures. If this were really due to replacement, it is significant that the two rock-types cut by the vein, although of very different composition, have been affected to precisely the same degree—the aplite is homogeneous and of the same width, though it cuts from granite into basic diorite. On the other hand in homogeneous material at the point where the vein splits, replacement suddenly became far less effective, though the feeding fissure goes on. Why should this be so? There can be no doubt that this structural feature also is characteristic of normal intrusion: no replacement is involved.

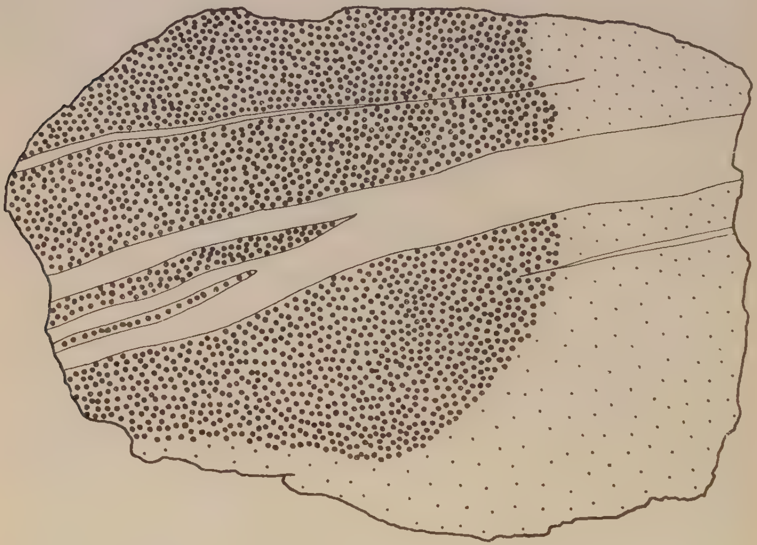


Fig. 8. Aplite-vein branching into three. Ronez, North Jersey.
Diorite xenolith: heavy stipple. Hybrid granite: light stipple. Aplite: blank. The unbranched aplite-vein is one inch wide

4. CHEMICAL CONSIDERATIONS

So far nothing has been said concerning the chemical evidence bearing on the problem of the nature of aplites. This is intentional since the purpose in this paper is to describe features, visible in the field and under the microscope, which may be used as criteria for distinguishing between intrusive and replacive rocks, with special reference to the aplites. Thus, on this basis, chemical evidence is beyond the scope of this paper; but it is reasonable to claim that the field and microscopic evidence discussed above is complementary to, and supports the chemical findings, particularly those stated recently by S. R. Nockolds (1947, pp. 19–28). In his paper, the chemical analyses of a large number of aplites from many parts of the world (though unfortunately not from Jersey, for none of these has as yet been analysed) have been plotted on a tetrahedron, the corners of which represent maximum modal quartz, orthoclase, albite and anorthite. The modes of these aplites lie either on or near the plagioclase–potassic felspar–quartz cotectic curve, or else on or near the plagioclase–quartz boundary-surface. The positions of the boundary-surfaces and, therefore, of the cotectic curve, were determined from experimental data. Now if granite aplites actually represent solidified residua or magmatic fractions, the course of crystallisation should follow that predictable from the phase-rule chemistry of a quaternary system, two components of which form an isomorphous series, immiscible with the remaining two components of the system. That the aplites, when plotted on such a diagram, do in fact fall on these boundary-surfaces exactly where, from purely theoretical considerations they would be expected to occur, is very strong evidence for their magmatic origin.

The authors agree with Nockolds when he says that the chemical evidence 'does not appear to be consistent with the view that they [the aplites] have been derived, directly or indirectly, from the activity of emanations acting on sedimentary or other rocks' (*op. cit.*, p. 24). D. L. Reynolds (1947, pp. 209–23), while maintaining the opposite view avoids some of the difficulties by explaining that aplites are rheomorphic—in other words the emanations so energised the material upon which they were working, that it became 'sufficiently fluid to become eruptive' (p. 212). On crystallising, such a 'melt' would follow the theoretical crystal-melt equilibrium relations. But this explanation, even if true, merely begs the question. There is still no explanation offered as to why ionic diffusion in the solid before rheomorphism is achieved, should ultimately produce a rock whose composition is identical with that predictable from observed experimental data.

One further point remains for consideration. Nockolds states that aplites represent residual liquids derived by crystallisation differentiation from a more basic magma; but he does not preclude the possibility that they may be the products of refusion, representing lowest melting-point mixtures, in those cases where such remelting can be proved to have taken place. In either case the essential granitic parentage of aplites remains a fact; for, if derived by refusion, it is probable that the material undergoing such refusion would be the granite itself rather than any other rocks.

5. CONCLUSION

Summarily, we regard the field relations of the aplites we have studied to be such as to render it highly probable that they are genuine intrusions and crystallised from a melt. It is correspondingly improbable that replacement has played any part in their genesis. It is necessary to emphasise that the authors are fully cognisant of the fact that aplites occurring in terrains, whose features indicate formation at low structural levels in the earth's crust, may well differ both in details of texture and mode of origin from the essentially high-level aplites described in this paper. It is only reasonable to expect that aplites associated with true plutons should differ from those of migmatitic complexes which occupy considerably lower positions in the Granite Series.

Crystallisation from a melt is indicated by the development of a chilled phase, by the clear evidence that crystallisation commenced on the margins of the sheets and veins, and by the direction of growth of some of the crystal-units, which was inwards from the margins. An important criterion is afforded by the absence of any appreciable 'basic front' phenomena, such as, in our experience, accompanies replacement which can be demonstrated on other evidence. We have satisfied ourselves that at least some of the graphic textures in aplites are primary structures, resulting, presumably, from the near-eutectic composition of the raw material from which the aplites crystallised.

It is probable that the criteria, which the authors have found useful in the study of aplites, may be equally valuable in solving similar problems where other rock-types are concerned.

ACKNOWLEDGMENTS

Finally, in the preparation of this paper the authors have benefited by discussion with Dr. M. K. Wells, Professor J. H. Taylor and Mr. R. W. D. Elwell. They are indebted to the technical staff at King's College under the direction of Mr. E. O. Rowland, for the preparation of thin sections. The junior author is grateful to the Department of Scientific and Industrial Research and the Central Research Fund of the University of London for grants towards the cost of research, some of the results of which are embodied in this publication.

REFERENCES

BILLINGS, M. P. 1925. On the mechanics of dike intrusion. *Journ. Geol.*, Chicago, **33,** 140–50.

GOODSPEED, G. E. 1940. Dilation and replacement dikes. *Journ. Geol.*, Chicago, **48,** 175–95.

HATCH, F. H., A. K. WELLS & M. K. WELLS. 1952. *The petrology of the Igneous Rocks*, 10th Edn., Murby.

JOHANNSEN, A. 1932. *A descriptive petrography of the igneous rocks*. **2,** Chicago.

KING, B. C. 1948. The form and structural features of aplite and pegmatite dikes and veins in the Osi area of the Northern Provinces of Nigeria and the criteria that indicate a non-dilational mode of emplacement. *Journ. Geol.*, Chicago, **56,** 459–75.

NOCKOLDS, S. R. 1947. The granitic cotectic curve. *Geol. Mag.*, London, **84,** 19-28.

REYNOLDS, D. L. 1947. The granite controversy. *Geol. Mag.*, London, **84,** 209 23.

ROBINSON, A. J. & A. E. MOURANT. 1936. Compte rendu de la réunion extraordinaire de la Société Géologique et Minéralogique de Bretagne à Jersey 1934. *Mem. Soc. Géol. Min. Bretagne*, **3**, 5–64.

DISCUSSION

DR. W. S. PITCHER agreed that, from the evidence presented by the authors, the purely magmatic character of many of the Jersey aplites had been convincingly demonstrated. It was possible to illustrate many of the features referred to in the paper among the numerous aplitic dykes accompanying the later intrusions of the Donegal Granite Complex. A structural control of emplacement was very evident; a relative movement of the dyke-walls was often apparent and in the same sense in numerous examples.

Pegmatite and aplite were intimately associated in Donegal, and within shallow dipping sheets the coarser crystals were often concentrated on the hanging wall and beneath stoped blocks. The felspars and micas hang as plumose intergrowths into the aplitic body. This phenomenon could be matched in those sheets occurring near Porthleven, Cornwall, and associated with the Godolphin Granite. The differentiation of a mobile volatile phase from a crystallising magma was clearly indicated by these examples. Chilling at the sharp contacts was not, however, a common feature, possibly because the granitic country rocks had not long consolidated at the time of emplacement of the dykes, and were relatively hot.

Although aplites in Jersey and Donegal could be shown to be magmatic, such a conclusion could not be all-embracing although largely true for minor intrusions associated with late, post-orogenic and upper-crustal granites.

DR. J. SUTTON congratulated the authors on their convincing account of the magmatic origin of the Jersey aplites and wished to express his appreciation of the way in which the authors had set out to demonstrate the magmatic origin of these rocks from the evidence available, rather than start from the assumption that these aplites must be magmatic.

Turning to the wider question of the origin of aplites in general, the speaker found difficulty in discussing the comments that had been made on the lantern slides illustrating other workers' results, as the papers from which these were taken had been discreetly left unnamed. One did not know whether these other examples of aplites came from the same sort of geological setting as the Jersey intrusions or not. The name of Dr. B. C. King had, however, been mentioned. Many of the aplites which that author had discussed occur in a granite-gneiss area in the Pre-Cambrian Basement Complex of Nigeria, where Dr. King had found them to be directly related to indefinitely bounded aplitic patches in the gneiss (B. C. King & A. M. J. de Swardt, 1949, *Geol. Surv. Nigeria*, Bull. 20). The processes by which such gneisses (excellently illustrated in the Bulletin) and their attendant aplites formed, might well be different from those recorded in Jersey.

The speaker had been puzzled by aplitic rocks in the Scottish Pre-Cambrian permeation complexes which showed many of the features described by Dr. King from Nigeria. He thought these puzzling features might best be explained by a metasomatic origin. He hoped that the authors would extend their review of the aplites by a study of these rocks in some extensive gneissose terrain.

PROFESSOR R. M. SHACKLETON said that he fully agreed with the authors' conclusions. He remarked that *both* the diagrams quoted by Dr. Wells from a paper by Dr. B. C. King (*Journ. Geol.*, **56**, 1948, p. 460, fig. 1A and B) were ambiguous. Dr. Wells had pointed out that a dyke would not appear to be offset if it were moved apart in a direction parallel to itself (cf. *op. cit.*, fig. 1B). The offset in Dr. King's fig. 1A need not imply dilation. The same geometry would result from replacement along a fault of appropriate slip. Both these alternative explanations require coincidences which are unlikely to be very frequent. Reliable estimates of dilation can be made when two non-parallel structures, for example two earlier dykes, are intersected by a later dyke.

The speaker enquired whether the direction of dilation had been determined in many cases in the area under discussion. He thought that it was too often assumed that dilation was normal to dyke-walls. One of the authors' illustrations showed offset oblique to the walls of a dyke offshoot. Accurate data of this kind could help in defining the stress-orientation at the time of intrusion.

DR. A. T. J. DOLLAR asked whether, in connection with the possible former distribution of volatiles in the parent aplitic fluid or fluids of Jersey, the authors had found any significant difference between the selvedge-textures of the dyke-like and sill-like aplite-sheets respectively, as was the case on Lundy, where, for example, numerous vertical aplite-sheets showed no coarse-grained marginal intergrowths whatever, while horizontal sheets, in the same country-rock and contemporaneous with, and of the same order of thickness as these dykes, possessed only an upper margin of this kind.

Also, he asked whether, on the assumption that at least some of these Jersey aplites were magmatic in origin, the authors knew of any contemporaneous, or pene-contemporaneous sheets of lamprophyric or allied basic composition which might suggest the former existence of a more basic magma-fraction, complementary to an aplitic one, as appeared to be true of the aplite suite of rocks on Lundy (A. T. J. Dollar, The Lundy Complex: its petrology and tectonics. *Quart. Journ. Geol. Soc. Lond.*, **97**, 1941, pp. 47–67).

DR. A. E. MOURANT traced his interest in the aplites of Jersey back to his earliest effort in practical geology when, as a schoolboy, about 1921, he had mapped some of these dykes. He wished to ask the authors for their views as to the relation in space, time and chemical composition between the Jersey aplites and the local granite magmas. Did they regard the aplites as bearing any special relationship to the aplogranites such as that of Beauport (St. Brelade) and Mont Mado? How did they account for the aplites which were found cutting a dolerite sill (as also mentioned by Miss Casimir) in the granite at the Pinnacle (NW. Jersey) and in profusion cutting the main NE.–SW. dolerite dykes in the granite at Pontac (SE. Jersey)?

DR. F. A. HENSON congratulated the authors on their interesting paper. He asked the authors, however, if they could reconcile their divergent comments upon the aplites at Elizabeth Castle described by Dr. Wells (where the earlier diorite marginal to the aplites is basified and granitisation phenomena occur), with the later comment by Mr. Bishop that aplites were extremely uniform in character and as intrusive phenomena traversed the country-rock without such effects. In the speaker's view the two cases were rather different from each other. In the Elizabeth Castle area the aplites are marginal phenomena associated with the emplacement of an aplogranite; the examples of aplites described from other areas by the authors represented late intrusive phenomena along fault- and fracture-planes.

The speaker also referred to aplites developed in the Pre-Cambrian sediments at Le Pulec, of which the authors exhibited an extremely interesting specimen. Dr. Henson maintained that this aplite was composite in character and showed photographs of this aplite and its relationship to the granite and the sediments. In the exposure from which the specimen on exhibition was taken, the aplite consists of two thin intrusive veins, which are separated by a central band of hornfelsed Pre-Cambrian sediments of variable thickness. Porphyroblastic felspars are strongly developed in this central band. The total thickness of this 'aplitic vein' is three inches in this exposure and, furthermore, is accompanied by marginal basification of the sediments above the upper aplite. The intrusive character of the aplites is clear, but local granitisation and diffusion phenomena have also taken place.

Finally, the speaker asked Dr. Wells if he would kindly elaborate on the Grosnez dolerite sills, since, from the speaker's knowledge of the exposure, the termination of the lower sill indicated the end of the fault or thrust-zone in the granite along which it had been intruded and its upward rise into the slightly higher level into a parallel tectonic feature. The path followed by the intrusion was to be seen in the exposure and was most likely another fault inclined to the plane of the sills.

MISS M. CASIMIR, in a written contribution, regretted that she was unable to be present at the reading of the paper, but looked forward to its publication. She asked the authors if they were familiar with the exposure of aplites traversing a dolerite sill a hundred yards north of the Pinnacle in NW. Jersey. Here aplitic veins ¾ to 1¼ in. in width traverse a dolerite two feet thick. This exposure supports the findings of the authors.

MR. R. W. D. ELWELL said that the structural and petrological evidence seemed to him to prove that the aplites under discussion were of magmatic origin. He enquired into the significance of the chemical evidence mentioned by the authors, and asked them whether there might be analyses of aplites quoted in the literature whose plotted values would be wide of the cotectic curve referred to. The presence of such would, perhaps, strengthen the suggestion, which derives from other evidence, that there might also be a category of metasomatic aplites.

THE AUTHORS, in reply, wished to thank the members for the kind reception of their paper, and in particular those who had taken part in the discussion. They were pleased to know that aplites of a comparable structural level in Donegal, described by Dr. Pitcher, show features closely similar to those described from Jersey. They are familiar with the composite aplite-pegmatite sheets near Porthleven. These are referred to in the paper, as they yield critical evidence favourable to the authors' contention that some aplites and pegmatites are magmatic.

The authors agree with Dr. Sutton that aplites found in low-level gneissose terrains may well be formed by processes other than dilation-injection; but it is quite unreasonable to argue that, because such low-level aplites appear to be metasomatic, all other aplites must be replacive too. The structural level of the country-rock must be taken into account when considering the origin of aplites, no less than in the case of granites.

In reply to Professor Shackleton, the opening of aplite fissures in Jersey is predominantly in a direction at right angles to the fissure walls, although there are some exceptions. The fact that horizontal as well as vertical movement along a fissure may complicate the interpretation of the structural relationships is fully realised, and is discussed in the paper.

In reply to Dr. Dollar, the majority of the Jersey aplites are sill-like in habit, and in a proportion of these no marginal intergrowth occurs; they are saccharoidal to the contacts, though chilled. Some of the aplites have the marginal intergrowth at both contacts; whilst in others it is thicker at the upper contact.

The authors are not aware of any thin sheets of basic rock which might be taken to correspond to a magma-fraction complementary to that from which the aplites crystallised. Lamprophyre dykes in variety occur in the island, but they are thought to have no connection, as regards origin, with the aplites.

Dr. Mourant raised an interesting question concerning the space-time relationship between the aplites and the granites. This aspect has received attention in the paper, but it is as well to reiterate that the aplites cut all the granites which they must therefore post-date; and that chemically they are more closely allied to the younger aplogranites (i.e., Beauport, Mont Mado and Elizabeth Castle) than to the older porphyritic types. This seems consistent with the view that they represent a late-stage residuum of an alkali-granite.

The authors are acquainted with the aplite which cuts the dolerite sill at the Pinnacle, mentioned by Miss Casimir and Dr. Mourant. The complexity of the time-relations of aplites and minor basic intrusions in south-eastern Jersey is emphasised by the work of Searle on the regional dyke-swarms, and by Casimir and Henson (1949) on intrusive phenomena at Dicq. These works record and figure basic dykes which cut aplites; but the former are not all of one age. Further, it is sometimes difficult to decide whether a given 'acid' sheet is genuinely aplitic (both as regards composition and origin), or merely an off-shoot of one of the microgranite sheets which occur in the island, often in the closest association with basic (basaltic or doleritic) rock.

Dr. Henson appears to have misunderstood the authors' comments concerning the differences between the granite sheets at Elizabeth Castle and the aplites in the same locality. The sheets with replacive contacts and minor basic fronts are of *hybrid granite*, not of aplite. The latter never show these phenomena, but everywhere in the island show straight, clean-cut margins, without basic fronts.

As regards Dr. Henson's comments on the composite aplite at Le Pulec, the authors regard some of his conclusions as open to a different interpretation. Serious structural difficulties arise if the marginal parts are regarded, as he suggests, as two separate transgressive sheets following parallel courses a few inches apart. Further, it is difficult to understand why the suggested metasomatism should be complete *between* these sheets, but should produce no effect on the country-rock outside. The latter, right up to the contacts, is a typical biotite-hornfels, very rich in biotite; but this mineral is as rare in the so-called 'hornfelsed Pre-Cambrian sediment' as it is in the marginal aplite. The authors are not convinced either that the felspars contained in the central part of the intrusion are porphyroblasts: there are none in the country-rock outside, and in contact with, the aplite; while some are locally developed in the marginal aplite. They regard the intrusion as a composite aplite, with an inner porphyritic member.

The sudden thinning, almost to vanishing point, of the basic sill at Grosnez occurs at the more southerly end of the exposure referred to in the paper, not at the more northerly end, where the sill changes its horizon, as noted by Dr. Henson.

Finally, in answer to Mr. Elwell, there are analyses of, in particular, sodic aplites which do plot wide of the cotectic curve and which were interpreted by Nockolds (1947) as being due to metasomatic modification.

Three Complete Sections of the Cornbrash

by W. J. ARKELL

Received 5 March 1953

CONTENTS

1. Sutton Bingham, Somerset ... ... page 115
2. Frome, Somerset 117
3. Fotheringhay District, Northamptonshire 120
References 122

SUMMARY AND INTRODUCTION: Since publication of a stratigraphical survey of the Cornbrash twenty to twenty-five years ago (Douglas & Arkell, 1928; 1932; see also 1935), complete new sections have been studied in southern Somerset (Sutton Bingham, near Yeovil), northern Somerset (Frome), and Northamptonshire (between Oundle and Wansford). They add considerably to what was previously known and have an important bearing on problems of faunal succession discussed in the previous papers, and since all the sections are temporary and will be filled in or grassed over, it seems desirable to record what was seen and the fossils that were collected when they were fresh. They include both the thickest (35 ft.) and thinnest (0 to 6 in.) developments of Cornbrash ever exposed and recorded.

---

1. SUTTON BINGHAM, SOMERSET

THE MOST southerly sections were measured in August 1952, in company with the Rev. Joseph Fowler of Sherborne, in the diversion channel for a new reservoir dam at Sutton Bingham, Somerset, and a borrow-pit near by. The works were being carried out by Messrs. Herbert Lapworth Partners for Yeovil Rural District Council. I am indebted to Mr. R. C. S. Walters, B.SC., M.INST.C.E., F.G.S., for permission to measure and collect, and to my friend, Mr. Fowler, for drawing my attention to the sections and for help with the collecting.

Owing to the usual lateral variations in such strata, thicknesses determined at different parts of the section may differ considerably, and the division into beds is largely subjective. No attempt was made to achieve accuracy of measurement beyond what the circumstances seemed to warrant. The following description and thicknesses, however, are at least consistent with those previously published by Prof. Douglas and myself for Cornbrash sections all over England, and so admit of comparisons.

The Cornbrash in this section is thicker (35 ft.) than in any other exposure yet seen in Britain. The principal feature of interest is the occurrence of the *Ornithella arenaria* Beds or 'Sands of the Cornbrash' *in situ* in a complete sequence. Buckman correlated these beds with the Hinton Sands facies of the Forest Marble, but Douglas & Arkell from isolated small sections concluded that they form part of the Upper Cornbrash (1928, pp. 121, 151). This is now confirmed.

The geology of the Sutton Bingham reservoir site as a whole is a larger subject, outside the scope of this paper.

SECTION OF CORNBRASH IN DIVERSION-CHANNEL FOR THE DAM, SUTTON BINGHAM (W.J.A., August 1952)

	ft.	in.
Upper Cornbrash (24 ft. 6 in.)		
10. Hard limestone	2	0
9. Brown marl		6
8. Tough limestones	4	0
7. Sandy brown marl full of crushed *Microthyridina calloviensis* (Douglas & Arkell) and *M.* cf. *lagenalis* (Schloth.)	1	0
6. Blue sandy clay, locally hardened to a marlstone, with *M.* cf. *lagenalis*	4	0
5. Tough limestone	4	0
4. Nodular buff limestone and sandy marl, with abundant *Ornithella siddingtonensis* (Walker), *O. arenaria* Buckman, and *Rhynchonelloidea gremifera* Buckman. *Meleagrinella echinata* (Wm. Smith) occurs. *Pholadomya deltoidea* (Sow.) abundant. The top 6 in. clayey, with a crushed macrocephalitid *in situ*	9	0
Lower Cornbrash (10 ft. 6 in.)		
3. Hard blue nodular limestone. *Ornithella obovata* (Sow.)	2	6
2. Blue marl with scattered nodules, *Ornithella obovata* (Sow.), abundant *M. echinata* (Wm. Smith), *Pholadomya deltoidea* (Sow.), *P. lirata* (Sow.), *Modiolus plicatus* (Sow.), etc.	3	6
1. Hard nodular to rubbly limestone. *Ornithella* cf. *obovata* (Sow.) tending towards *O. classis* Douglas & Arkell. Abundant myacean casts	4	6
Mr. John Callomon on a subsequent visit found *Cererithyris intermedia* (Sow.) at the top and 1 ft. from base, and also noted *Pygurus*.		
Forest Marble (seen to c. 12 ft.)		
Blue clay and shale, some lignite; and about 10 ft. down, an impersistent band of hard, shelly, oolitic limestone up to 1 ft. thick.		

On the tip-heap *Kallirhynchia yaxleyensis* (Dav.) and *Ornithella magnobovata* (Buck.) occurred rarely, in blue soft matrix, presumably Bed 2. In the office we were shown a gigantic smooth *Macrocephalites* in hard limestone, and we found half another on the tip-heap. Mr. Fowler obtained a fragmentary *Macrocephalites* (*Kamptokephalites*) sp. from Bed 5 or Bed 8, and Mr. John Callomon was shown a fragment of *Choffatia*.

In a borrow-pit for road diversion No. 1, immediately south of Sutton Bingham station, vast numbers of brachiopods and other fossils were excavated from about 8 ft. of rock, which could only be Bed 4 of the main section. It is here developed in a more sandy facies: buff sandy marl with small, hard, buff nodules (5 ft.), overlain by 3 ft. 3 in. of rubbly limestone and underlain by a more solid bed of purplish nodular limestone (seen to 8 in.). The fauna noted or collected in these 5 ft. of 'Sands of the Cornbrash' is as follows:

> *Macrocephalites* (*Dolikephalites*) cf. *typicus* Blake (found by Mr. Fowler 1½ ft. above base of the sandy marls).
> *Macrocephalites* (*Macrocephalites*) *jacquoti* (H. Douvillé).
> *Ornithella siddingtonensis* (Walker)
> ,, *arenaria* Buckman } extremely abundant.
> *Rhynchonelloidea gremifera* Buckman
> ,, *cerealis* Buckman.
> *Pholadomya deltoidea* (Sow.).
> *Pleuromya uniformis* (Sow.).
> *Thracia depressa* (Sow.).
> *Goniomya literata* (Sow.).
> *Gresslya peregrina* (Phil.).
> *Meleagrinella echinata* (Wm. Smith).
> *Pinna ampla* (Sow.) (= *reticulata auct.*).
> *Trigonia* sp. (casts).
> (For interpretation of the lamellibranchs see Cox & Arkell, 1948–50.)

The *Ornithella* population has the characteristic stamp of the *siddingtonensis* Subzone, which, though difficult to define, enabled the subzone to be recognised in dozens of exposures in south and central England, but numerous specimens may be picked out which when taken by themselves seem indistinguishable from some varieties of *O. obovata*; and the recognition of certain forms as *O. arenaria* is equally arbitrary.

2. FROME, SOMERSET

At the opposite end of the county, twenty-seven miles NE. of Sutton Bingham, two complete sections of the Cornbrash and underlying and overlying formations were opened in 1931–2 in cuttings for the Great Western Railway's new loop-line to avoid Frome station. I recorded descriptions in May 1931, and in August 1932, and collections of fossils were made by the Geological Survey, but, excepting a brief mention of the principal horizons present (Arkell, 1933, p. 330), nothing has yet been published. Since the ammonites have meanwhile been studied, and the section and palaeontology make interesting comparisons with Sutton Bingham, it seems time to put the section on record in print. I wish to express my appreciation of the co-operation of the Geological Survey in sending me the ammonites on loan and allowing details to be published.

The total thickness is less than a third of that at Sutton Bingham. Almost the whole reduction is at the expense of the Upper Cornbrash, which is 1 ft. thick as compared with 24½ ft. at Sutton Bingham. The Lower Cornbrash remains about the same, 8¼–9½ ft. in the two railway-cuttings, as compared with 10½ ft. at Sutton Bingham.

SECTION OF CORNBRASH IN SOUTHERLY RAILWAY-CUTTING EAST OF FROME (W.J.A., May 1931).

Kellaways Clay

Upper Cornbrash (10 in.)	ft.	in.
4c. Rusty marl		3
4b. Shelly rotten limestone full of *Rhynchonelloidea cerealis* Buckman and *Ornithella siddingtonensis* (Walker), with *Trigonia scarburgensis* (Lycett), etc.		4
4a. Brown marl		3
Lower Cornbrash (8 ft. 3 in.)		
3. Solid block of hard purplish-grey sandy limestone. *Meleagrinella echinata* (Wm. Smith) and occasional *Ornithella obovata* (Sow.) (the latter seen in section only) occur throughout. The lowest 1½ ft. is full of these and other shells, especially *Trigonia angulata* Sow., *T. crucis* Sharp (=*rolandi* Cross), *Astarte hilpertonensis* Lycett. Top surface piped (and bored?)	3	6
2. Rubble and marl with *Ornithella obovata* (Sow.)	3	6
1. Hard cream-coloured limestone with *Cererithyris intermedia* (Sow.)	1	3

Forest Marble clays below (seen to 30 ft.)

In the more northerly cutting the lithology and thicknesses are already somewhat different. In the following independent description, made a year later, the beds are numbered to correlate with the southern cutting.

SECTION OF CORNBRASH IN NORTHERLY RAILWAY-CUTTING, EAST OF FROME (W.J.A., August 1932).

Kellaways Clay with selenite.

Upper Cornbrash (1 ft.)	ft.	in.
5. Layer of clay crowded with small *Exogyra* and *Rhynchonelloidea* cf. *cerealis* Buckman, also *Ostrea undosa* Phil. and *Lopha marshi* (Sow.)		
4. Nodular limestone, hard, purplish, inky-centred, rusty-coated, with irregular upper and under surfaces	1	0
Lower Cornbrash (9 ft. 6 in.)		
3. Hard purplish limestone, as in S. cutting, with irregular upper surface. *Pygurus* additional to other fossils	4	0
2b. Rubble and yellow marl with abundant *Ornithella obovata* (Sow.), etc.	1	0
2a. Rubbly limestone, blue-grey, black-specked; *M. echinata* abundant, and many casts of *Pleuromya*, *Ceratomya*, *Cardium*, etc.	3	0
1. Cream-coloured, grey-centred limestone	1	6

Forest Marble clay, seen to about 4 ft.

To the north of this section, under the bridge, a fault throws down north and the cutting north of the bridge exposed a complete section of the Kellaways Beds (published in Arkell, 1934, p. 55).

From material excavated from Bed 3 of the Cornbrash, Dr. F. B. A. Welch and Mr. S. W. Hester in 1931–2 collected seven specimens and fragments of perisphinctid ammonites. I have studied these in connection with all other available Cornbrash material and identify them as follows:

Choffatia subbakeriae (d'Orb.) (=*longilobata* Buckman sp.) (Geol. Surv. Mus. Ht. 853, Ht. 854).
Choffatia sp. nov. No. 1 (GSM. Ht. 855).
,, sp. nov. No. 2 (GSM. BW 144, BW 147).
,, (*Homoeoplanulites*) *homoeomorpha* (Buckman) (=*stabilis* Buck.) (GSM. BW 150, BW 148).

Judging by the lack of shells in the matrix of the ammonites, they came from the upper part of the bed. The new species have been described in MS. in my Palaeontographical Society monograph, but cannot be published for several years. The distribution of the four species in other localities, so far as known, is as follows:

Choffatia subbakeriae: Berkley, near Frome; judging by the matrix, from the same bed (see Arkell, 1933, p. 330) (GSM. 1852 HBW). Sherborne District (Sherborne School Mus.) and probably Sherborne district (Bower Coll., Taunton Castle Mus. 3266–7, 3303). Long Hanborough, Oxon (GSM. 37364 and 83149), almost certainly from Lower Cornbrash.

Choffatia sp. nov. No. 1: Berkley, near Frome; judging by the matrix, from the same bed (GSM. 1344 HBW). Probably Sherborne district (Bower Coll., Taunton Castle Mus. 3304). Near Charlbury, Oxon (Oxford Univ. Mus. J 1392), almost certainly from Lower Cornbrash.

Choffatia sp. nov. No. 2; Long Hanborough, Oxon (J. M. Edmonds Coll., 1950, Oxford Univ. Mus. J 1370), almost certainly from Lower Cornbrash.

Choffatia homoeomorpha: Stalbridge Weston, Dorset (holotype, GSM. 8654) and fragment of a topotype, W. J. Arkell Coll. (Sedgwick Mus. J 20354) collected 1948 *in situ* in Lower Cornbrash, *obovata* Subzone. Shorncote, Glos., Bed 1 (W. J. Arkell Coll.), *in situ* in Lower Cornbrash with *Clydoniceras*, etc. (see Douglas & Arkell, 1928, p. 135). Near Oxford (Oxford Univ. Mus. J 920), probably from Lower Cornbrash. Fairford (Nottingham Univ.). Cirencester (Reading Univ.). Near Sherborne (Taunton Castle Museum, 3268).

An indeterminable *Choffatia* was also found in Lower Cornbrash on the Fleet shore south of Abbotsbury (Douglas & Arkell, 1928, p. 153, recorded as *Homoeoplanulites*). On the other hand, at Stalbridge and Corscombe, *Choffatiae* were found in Upper Cornbrash, associated at Corscombe with *Macrocephalites* (*Kamptokephalites*), and at Holwell in a block presumed to have fallen from Upper Cornbrash (Douglas & Arkell, 1928, pp. 147, 148, 152). It appears, therefore, that while the principal horizon of *Choffatiae* of the *subbakeriae* group in this country is Lower Cornbrash (Bathonian), similar forms also occur in the Upper Cornbrash (Callovian). It is necessary, however, to correct the impression that the principal *Choffatia* beds in this country are Upper Cornbrash, as implied by Blake (1905, p. 51) and Buckman (1922, pl. CCCXXVIII; 1924, pl. DXV; 1925, pl. DXCVI) and accepted by Douglas & Arkell (1928, p. 143, footnote).

The *Choffatia* Bed in the Frome cuttings (Bed 3) is certainly the 'iron-hard band' (Bed 5) at Cards Farm, South Brewham (Douglas & Arkell, 1928, pp. 144, 145) and the hard 'cream-coloured sandy limestone' at Berkley (*ibid*, p. 143) from which we and our predecessors obtained *Choffatia*, but the likeness to the *siddingtonensis* Beds of Poulton, Garsden, etc., which influenced us in assigning it to the Upper Cornbrash, was deceptive (as already pointed out: Arkell, 1933, p. 330).

It is remarkable that no *Macrocephalites* was found at Frome and only one *Choffatia* at Sutton Bingham. Since both genera have almost world-wide distribution, some stratigraphers would infer that there is a non-sequence in both sections. There is no difficulty in this explanation to account for the absence of the *Macrocephalites* Beds at Frome, where the 24½ ft. of Sutton Bingham Upper Cornbrash is only 10–12 in. thick; but it seems less convincing at Sutton Bingham, where the Cornbrash is so thick.

3. FOTHERINGHAY DISTRICT, NORTHAMPTONSHIRE

In the third area investigated, between Oundle and Wansford, Northamptonshire, the Cornbrash is so thin that complete sections have been seen in roots of upturned trees and in field ditches. The Cornbrash, celebrated for its extraordinary persistence from Weymouth to Scarborough, is here reduced to a band of irony nodules three or four inches thick, sometimes overlain by a foot or so of brashy rottenstone, and borings and mapping have indicated that in some places it may disappear altogether.

This was discovered by members of the Geological Survey during their investigation of the ironstone field, begun in 1939, and has been briefly published in the 'Ironstone Memoir' (Hollingworth, Taylor, Wilson, *et alii*, 1951, p. 22): as follows:

> The Cornbrash extends throughout the Ironstone Field as a remarkably persistent bed of limestone normally between 4 and 6 ft. thick. Locally, it is thinner and near Apethorpe and Southwick it is reduced to a nodular band only a few inches thick. Borehole records suggest that over very limited areas in the neighbourhood it may be completely absent. The maximum thickness developed in the Field is 10 ft.

During 1948–50, I mapped the valley of the lower Nene, between Oundle and Wansford, and the edges of the plateau on either side, and discovered independently that the Cornbrash is absent or only a few inches thick in certain places west of the river. Since it is present in normal form all along the east side, and is known from complete sections to be 8 ft. thick at

Barnwell, near Oundle (Douglas & Arkell, 1932, p. 132), and 5 ft. thick at Fineshade on the west side (Blake, 1905, p. 14), the discovery presented a puzzling problem in the absence of exposures. At first I attributed my failure to find the Cornbrash on certain spurs where it should crop out to denudation and to the presence of an unexpected thickness of boulder clay, incorporating large quantities of Kellaways Beds. In other places the surface of the Blisworth Clay is thinly scattered with fragments of clay-ironstone nodules. These were taken to be part of the Blisworth Clay, which contains such nodules: in the Peterborough district they are common enough to have been formerly collected for trial smelting as an iron-ore (Judd, 1875, p. 217); but here they are, in fact, of Cornbrash age.

The first place where anomalous absence of recognisable Cornbrash was encountered is a spur partly occupied by Cotterstock Wood, two miles SW. of Fotheringhay. Judd (1875, p. 224) stated that 'the Cornbrash with its usual fossils is well exposed on the south side of Cotterstock Wood', but for once he must have mistaken for Cornbrash the somewhat similar Great Oolite limestone, which is well displayed in fields beside the Cotterstock road south of the wood.

In 1951 the Kettering sheet of the one inch Geological Survey map was published: a work that must evoke the admiration of anyone acquainted with the area. It marks a continuous very narrow outcrop of Cornbrash all round the Cotterstock Wood spur, and in 1953 Dr. Vernon Wilson demonstrated to me that even in the most unpromising places some of the irony nodules can be found on the featureless clay slopes. On the next hill spur to the south, only three-quarters of a mile away, the Cornbrash is well developed and forms a normal stony plateau round the western outskirts of Oundle.

Another place where sudden reduction and change of facies in the Cornbrash has been observed is a hill two miles NW. of Fotheringhay and one mile W. of Nassington. Here extensive reclamation measures were undertaken in 1951, resulting in a complex of exposures. A large wood, Mountjoy Sale, was destroyed by pulling up the trees by their roots, ditches were dug for a foot or two into the subsoil, and the surrounding fields were trenched for land drains. The Cornbrash here consists of a band of irony nodules, about 3–4 in. thick, crowded with brachiopods and other fossils, overlain by a foot or two of fossiliferous rottenstone, in which (among tree-roots in Mountjoy Sale) I found a fragment of *Macrocephalites*, proving Upper Cornbrash. *Lopha marshi* (Sow.) forms a noticeable band at the top. The top of the underlying Blisworth Clay is an oyster lumachelle (small *O. hebridica* Forbes?). From tree-roots and a deepened ditch along the south side of Mountjoy Sale the following fossils were collected (brachiopods) or noted (others):

Ornithella obovata (Sow.) (abundant).

Ornithella magnobovata (Buckman) (abundant)
„ *siddingtonensis* (Walker) (abundant)
Cererithyris, small forms.
Kallirhynchia yaxleyensis (Dav.)
Lopha marshi (Sow.) (abundant)
Ostrea undosa Phillips
Exogyra nana (Sow.)
Meleagrinella echinata (Wm. Smith)
Chlamys anisopleurus (Buv.)
Lima rigidula Phillips
Pseudolimea duplicata (Sow.)
Trigonia crucis Sharp
Modiolus bipartitus Sow.
Pygurus sp., fragment
All the usual Myacea

Most of these fossils, probably all the brachiopods, come from the nodules, which palaeontologically combine the *obovata* and *siddingtonensis* Subzones and therefore bridge the Lower and Upper Cornbrash. The nodules are a condensed version of Beds 1 and 2 at Thrapston (there respectively 5 and 6 in. thick). Beds 5 and 6 at Barnwell are also comparable (Douglas & Arkell, 1932, pp. 130, 132).

Within 400 yds. to the north, in a faulted spur that extends across the railway-cutting near New Sulehay, the Cornbrash has returned to the facies of hard, purplish, poorly-fossiliferous, flaggy limestone, with a marly layer at the top full of *Lopha marshi*. This development was described as normal for the district by Judd (1875, pp. 218–19), and was exposed at Fineshade cutting (Blake, 1905, p. 14). The hard band is Bed 4 at Thrapston (3 ft.) and Bed 8 at Barnwell (2 ft.) (Douglas & Arkell, 1932, pp. 130–2).

I wish to thank Dr. Vernon Wilson, Mr. Joseph Fowler, and Mr. John Callomon for reading the paper in typescript and for information and criticism.

REFERENCES

ARKELL, W. J. 1933. *The Jurassic System in Great Britain*. Oxford.

———. 1934. The oysters of the Fuller's Earth. *Proc. Cotteswold Nat. Fld. Cl.*, **25**, 21.

BLAKE, J. F. 1905–7. Monograph of the fauna of the Cornbrash. *Monogr. Palaeont. Soc.*, London.

BUCKMAN, S. S. 1919–30. *Type Ammonites*, **3–7**.

COX, L. R. & W. J. ARKELL. 1948–50. Survey of the Mollusca of the British Great Oolite Series. *Monogr. Palaeont. Soc.*, London.

DOUGLAS, J. A. & W. J. ARKELL. 1928. The stratigraphical distribution of the Cornbrash: 1, the south-western area. *Quart. Journ. Geol. Soc. Lond.*, **84**, 117.

———. 1932. *Idem*; 2, the north-eastern area. *Ibid.*, **88**, 112.

———. 1935. On a new section of fossiliferous Upper Cornbrash of north-eastern facies at Enslow Bridge, near Oxford. *Ibid.* **91**, 318.

HOLLINGWORTH, S. E., J. H. TAYLOR, V. WILSON, *et alii*. 1951. The Northampton Sand Ironstone: stratigraphy, structure and reserves. *Mem. Geol. Surv.*

———. 1951. Kettering sheet (171), one inch to mile. *Geol. Surv.*

JUDD, J. W. 1875. The geology of Rutland. *Mem. Geol. Surv.*

A Technique for the Removal of Skeletal Remains from Bone-Bed

by J. GRIFFITH

Department of Biology, Guy's Hospital Medical School, London

Received 15 May 1953

IN CONNECTION with some work on teeth of Mesozoic fishes a method has been developed that permits large numbers of such teeth to be quickly obtained from samples of bone-bed. It has been successfully employed with samples of the *Ceratodus* and other similar bone-beds from the Rhaetic of Gloucester, Somerset and Glamorgan. These beds consist of a conglomerate, cemented mainly by calcium carbonate, containing numerous fish teeth, scales, bones and fin-spines, together with occasional remains of saurians. As this method reduces to a minimum the tedious and time-consuming business of hand sorting and enables large quantities of bone-bed to be thoroughly examined, it is thought that it may prove of interest to workers in similar fields.

The bone-bed is broken down into its constituents by attacking the cementing substance with acid, followed by separation by floatation and sieving. Pieces of bone-bed are washed in water to remove adhering shale and marl, placed on edge in a glass tank and covered with acid. As has been recorded by other authors (Ewing, 1950; Rixon, 1949; Toombs, 1948) the most satisfactory breakdown is obtained by using diluted acetic acid, and it has been found that the best results are given by a large volume (five to ten times the volume of bone-bed treated) of approximately 15% acetic acid. The tank is then covered to trap the spray arising from the resulting vigorous effervescence. When the acid has become exhausted the action ceases, then the fluid is carefully poured off and the remaining contents of the tank are washed for a short time in running water. It is usually found that the sample now consists of two fractions; (*a*), some remaining pieces of bone-bed, and (*b*), many small fragments and particles which have been freed by the removal of the cementing substance.

The small fragments and particles (fraction *b*) are placed in another vessel and are subjected to further washing which removes both the remaining water soluble substances and the finest of the insoluble substances; the residue is then dried in the air or by gentle heat. It is necessary to remove the soluble substances and colloidal particles carefully before drying, as otherwise the particles tend to form firm lumps which are difficult to deal with subsequently. Any remaining pieces of bone-bed (fraction *a*) are returned to the tank and fresh acid is added. These processes are repeated until the whole sample has been broken down.

The mixture of skeletal remains and mineral matter is then sieved. A set of four small sieves with 10, 20, 30 and 40 meshes to the inch is employed; thus the material is divided into five grades. It has been found that the 40 – fraction consists almost entirely of broken skeletal fragments and fine mineral matter and is not further treated. The 10+ fraction is found to consist of small pieces of bone-bed, fragments of marl, shale, quartz and the larger skeletal remains. This is hand sorted and some of the pieces of bone-bed returned to acid for further breakdown. The remaining fractions, which usually contain the bulk of the material, are further separated by floatation with bromoform ($CHBr_3$). The specific gravity of the commercial qualities used varies between 2.85 and 2.90. The lighter fractions are found to consist of mineral matter containing no skeletal material; whereas the heavy fractions contain all the skeletal material and little mineral matter. The light fractions are decanted off, and all fractions filtered to recover the bromoform. After drying, the heavy fractions are hand-sorted under a low-power binocular microscope.

As mentioned above the chief advantages of the method are that it enables large quantities of material to be dealt with speedily, but, of course, this method is wasteful in so far as portions of damaged specimens may become separated, but as large amounts of bone-bed were available for treatment, this is of minor importance. It is considered advisable to remove the teeth from the acid at intervals of five or six days as prolonged exposure to acid decreases the yield of complete specimens. A number of teeth of different types have been sectioned and their microscopic structure does not appear to have been affected by the acid. Sieving into fractions, each containing particles of approximately the same size, is convenient for two reasons; firstly, the light and heavy fractions separate more quickly during floatation with bromoform than if the range of particle size is great and, secondly, hand sorting is easier as small objects do not get hidden under larger ones; further, it is possible to adjust the magnifying power of the microscope according to the size of the particles being examined.

REFERENCES

Ewing, J. F. 1950. A new technique for removing bones from limestone breccia. *Antiquity*, London, **94**, 102.

Rixon, A. E. 1949. The use of acetic and formic acids in the preparation of fossil vertebrates. *Mus. Journ.*, London, **49**, 116.

Toombs, H. A. 1948. The use of acetic acid in the development of vertebrate fossils. *Mus. Journ.*, London, **48**, 54.

Foraminifera from the London Clay

by R. N. C. BOWEN

Received 5 October 1953

CONTENTS

1. INTRODUCTION ... page 125
2. PAST WORK ... 126
3. COLLECTION AND SEPARATION OF SAMPLES ... 126
4. IDENTIFICATION ... 131
5. CLASSIFICATION ... 131
6. SYSTEMATIC RECORD ... 132
7. PALAEOECOLOGY ... 169
8. STRATIGRAPHICAL DISTRIBUTION ... 170
9. STRATIGRAPHICAL SIGNIFICANCE ... 172

ACKNOWLEDGMENTS ... 172

EXPLANATION OF FIGURES ... 173

LIST OF SELECTED REFERENCES ... 174

ABSTRACT. A systematic study of the Foraminifera from the London Clay of six localities in the London and Hampshire Basins resulted in 137 species and varieties being recorded, including 9 new species and 1 new variety. A short review of previous research is given and the lithology of the strata and the palaeoecology of the Foraminifera are discussed. The zonal significance of the Foraminifera is assessed.

---

1. INTRODUCTION

DURING THE YEARS 1948 and 1949, a series of bores was drilled by the Metropolitan Water Board in the Enborne Valley (Berkshire) in connection with a reservoir project. In 1950, 119 samples from eighteen of these bores were made available to the author, subsequently being analysed and the faunal contents noted. The Foraminifera were found to be predominant as regards both numbers of species and individuals. The occurrence of large numbers representing many species in an excellent state of preservation led to the extension of the study to other localities, firstly to 15 samples derived from bores drilled by the Ministry of Works in 1949 in the vicinity of the British Museum (Natural History), South Kensington, and later to samples from the Isle of Sheppey, from the London Brick Company's pit at Oxshott, Surrey, and from the Hampshire Basin where material was obtained from the magnificent coastal sections in the Isle of Wight, 15 samples being collected from Alum Bay and 10 from Whitecliff Bay. The principal objectives of the research were to find the vertical ranges of the species and varieties (thus establishing their zonal significance), to define them accurately and revise their taxonomic position where necessary and to relate them to the lithology of the strata.

2. PAST WORK

While a number of papers on the Foraminifera of the London Clay were published during the nineteenth century, the majority comprised little more than faunal lists either not illustrated or inadequately so. The most important, and detailed, were two, written by C. D. Sherborn & F. Chapman, in 1886 and 1889 respectively. The material described and figured by them has been examined by the present author at its depository, the British Museum (Natural History). More than 100 species are represented in this collection, of which 89, described in the earlier paper, were obtained from the drainage works carried out at Piccadilly, London, in 1885 and the remainder lent by J. W. Judd. The identifications and figures of some of these species are inaccurate. The specimens were mounted as permanent preparations on Franke-type slides which are covered by circular glass cover-slips attached by mucilage and could only be examined visually. Nevertheless, the information derived from them was useful as a check on the degree of precision of the papers. Where the latter is not high, appropriate comments have been made in the remarks on the relevant species in the present paper. In their earlier paper, Sherborn & Chapman noted the variability of the Foraminifera and stated their belief that, 'except in rare cases . . . the word "species" should stand "variety" '. At the end of this paper, they included a list of all the species previously recorded from the London Clay. None of the papers prior to these is worthy of examination and, among later papers, only those of A. G. Davis on the geology of the City and South London Railway extensions and the occurrence of Foraminifera in the London Clay at Sheppey, published in 1928 and 1936 respectively, need be mentioned.

3. COLLECTION AND SEPARATION OF SAMPLES

A severe drawback encountered in utilising the results of past work arose from inaccuracy in collection and it was decided to eliminate this factor as far as possible in the present investigation. In the case of material obtained from bores, this was effected by taking samples at known depths and relating them to the base of the London Clay where this could be estimated. With material collected from pits and coastal sections, accurate positioning was possible by referring the samples to known datum-lines within the Clay.

The Enborne Valley samples were obtained from eighteen bores and the depths of samples together with the lithologies of the beds from which they came must be recorded for each bore.

Bore 1: 1 sample from a depth of 150 ft. below the surface. Grey silty clay.

Bore 21: 7 samples from the following depths below ground level. The surface is at 307.1 ft. O.D.
32.5 ft. Grey clayey silt.
35.5 „ Grey clayey silt.
35.75 „ Grey clay.
60.4 „ Grey sandy clay.
61.6 „ Grey sandy clay.
75.5 „ Grey sandy clay.
96.2 „ Grey silty clay.

Bore 22: 4 samples from the following depths below ground level. The surface is at 242.2 ft. O.D.
43 ft. Grey clay.
51.5 „ Grey clay
61 „ Stiff grey clay.
81.25 „ Grey clay.

Bore 28: 6 samples from the following depths below ground level. The surface is at 228.2 ft. O.D. and the base of the London Clay is at 105 ft. depth.
29.2 ft. Stiff grey clay.
32.3 „ Stiff grey clay.
37.4 „ Stiff grey clay.
46.7 „ Stiff grey clay.
56.75 „ Grey clay.
86.5 „ Grey sandy clay.
Samples taken from 106 and 114 ft. were in mottled clay and were devoid of organic content.

Bore 29: 4 samples from the following depths below ground level. The surface is at 246 ft. O.D.
45 ft. Grey clay.
56 „ Grey clay.
63 „ Stiff grey clay.
79 „ Grey clay.

Bore 31: 12 samples from the following depths below ground level. The surface is at 207.9 ft. O.D. and the base of the London Clay is at 83.5 ft. depth.
7.67 ft. Brown clay.
12.6 „ Stiff grey clay.
17.5 „ Stiff grey clay.
20.2 „ Stiff grey clay.
23 „ Stiff grey clay.
26.75 „ Grey clay.
29.25 „ Grey clay.
42.6 „ Grey silty clay.
52.34 „ Bluish-grey clayey silt.
62.75 „ Bluish-grey clayey silt.
72.75 „ Dark clayey sand with shells.
82.5 „ Sandstone.
A sample taken from 94 ft. was in mottled clay and was devoid of organic content.

Bore 32: 6 samples from the following depths below ground level. The surface is at 203.5 ft. O.D.
16.8 ft. Grey clay.
25.5 „ Grey clay.

28.5 ft. Grey clay.
31.9 ,, Grey clay.
34.34 ,, Grey clay.
45.2 ,, Grey lignitic clayey silt.

Bore 33: 3 samples from the following depths below ground level. The surface is at 204 ft. O.D.
30 ft. Grey shelly clay.
33 ,, Grey silty clay.
38.5 ,, Grey silty clay.

Bore 34: 8 samples from the following depths below ground level.
32.75 ft. Grey clay.
35.5 ,, Grey clay.
39 ,, Grey clay.
40.34 ,, Dark grey silty clay with shells.
49.5 ,, Dark clayey silt.
59.5 ,, Dark grey silty clay with shells.
70.67 ,, Grey sand.
79 ,, Grey silty clay.
Three samples taken from 83 ft., 84.25 ft. and 91 ft. were in mottled clay and were devoid of organic content.

Bore 36: 8 samples from the following depths below ground level. The surface is at 228.7 ft. O.D. and the base of the London Clay is at 99 ft. depth.
19.34 ft. Stiff dark grey clay.
21.5 ,, Stiff dark grey clay.
24.5 ,, Grey clay.
30 ,, Stiff dark grey clay.
40 ,, Stiff dark grey clay.
49.5 ,, Pebble-bed.
60 ,, Grey clayey silt.
69.34 ,, Grey clayey silt.
Two samples were taken from 102.2 ft. and 109.5 ft. and consisted of mottled clay devoid of organic content.

Bore 37: 4 samples from the following depths below ground level.
30 ft. Grey sandy clay.
36 ,, Grey silty clay.
51 ,, Dark grey pebbly clay.
61.75 ,, Stiff dark grey clay.

Bore 38: 28 samples from the following depths below ground level. The surface is at 316.8 ft. O.D. and the base of the London Clay is at 165 ft. depth.
25 ft. Grey loamy silt.
30 ,, Greenish sandy clay.
35 ,, Stiff dark grey clay.
40 ,, Grey silty clay with lignite and pyrites.
45 ,, Pebble-bed.
50 ,, Grey sandy clay.
55 ,, Grey sandy clay.
60 ,, Grey clayey silt.
65 ,, Grey clayey silt.
70 ,, Grey silty clay.
75 ,, Pebble-bed.
80 ,, Stiff grey clay.

85 ft.	Stiff grey clay.
90 ,,	Stiff grey silty clay.
95 ,,	Stiff grey silty clay.
100 ,,	Stiff grey silty clay.
105 ,,	Stiff grey clay.
110 ,,	Stiff grey clay.
115 ,,	Stiff grey clay.
120 ,,	Stiff grey clay.
125 ,,	Stiff grey clay.
130 ,,	Stiff grey clay.
135 ,,	Grey clay.
140 ,,	Pale grey clay with small claystones.
145 ,,	Greenish silty clay.
150 ,,	Dark grey clay.
155 ,,	Dark grey sandy silt.
160 ,,	Dark grey sandy silt.

Bore 39: 3 samples from the following depths below ground level. The surface is at 349.8 ft. O.D.

100 ft.	Stiff grey clay.
131 ,,	Stiff grey clay.
160 ,,	Grey shelly clay.

Bore 41: 2 samples from the following depths below ground level. The surface is at 318.5 ft. O.D.

94.34 ft.	Dark grey silty clay.
104.8 ,,	Dark grey silty clay.

Bore 42: 2 samples from the following depths below ground level. The surface is at 272.5 ft. O.D.

53 ft.	Grey silty clay.
63 ,,	Grey clay.

Bore 52: 4 samples from the following depths below ground level. The surface is at 213.1 ft. O.D.

60 ft.	Stiff grey shelly clay.
63 ,,	Stiff grey shelly clay.
75 ,,	Very stiff grey clay.
78 ,,	Large green-coated pebbles in grey clay.

Bore 55: 3 samples from the following depths below ground level. The surface is at 239.9 ft. O.D.

56 ft.	Grey silty clay.
76 ,,	Grey silty clay with lignite.
101 ,,	Very stiff grey clay.

Bore 71: 6 samples from the following depths below ground level. The surface is at 213.5 ft. O.D.

25.2 ft.	Grey silty clay with lignite and Pinna.
27.67 ,,	Grey lignitic silty clay.
30.8 ,,	Grey lignitic silty clay.
33.67 ,,	Grey silty clay with lignite.
70 ,,	Stiff grey clay.
80 ,,	Grey clay.

(The numbers of the bores are those assigned to them by the Metropolitan Water Board.)

The South Kensington samples were derived from four bores drilled in the vicinity of the British Museum (Natural History), Bore 1 being to the north of the old Science Museum building, Bores 2 and 3 within the new building to the west of the new Science Museum in Exhibition Road and Bore 4 slightly north of the Cartway and about 50 ft. east of the southern entrance of the Old Spirit Building.[1] The depths of samples together with the lithologies of the beds from which they came must be recorded for each bore.

Bore 1: 2 samples from the following depths below ground level. The surface is at 28.52 ft. O.D.

22 ft.	Dark blue clay.
27 ,,	Dark blue clay.

Bore 2: 5 samples from the following depths below ground level. The surface is at 27.79 ft. O.D.

22.5 ft.	Dark blue clay.
27.5 ,,	Dark blue clay.
33.5 ,,	Dark blue clay.
43 ,,	Dark blue clay.
48 ,,	Dark blue clay.

Bore 3: 5 samples from the following depths below ground level. The surface is at 28.03 ft. O.D.

26.5 ft.	Dark blue clay.
33.5 ,,	Dark blue clay.
38.5 ,,	Dark blue clay.
43.5 ,,	Dark blue clay.
49.5 ,,	Dark blue clay.

Bore 4: 3 samples from the following depths below ground level. The surface is at 24.52 ft. O.D.

30 ft.	Dark blue clay.
35 ,,	Dark blue clay.
40 ,,	Dark blue clay.

(The numbers of the bores are those assigned to them by the Ministry of Works.)

The samples obtained from the Isle of Sheppey were collected from the Upper London Clay between Merryman's Hill and Round Hill to the north of Minster. Seven samples were examined and they comprised stiff dark brown clays.

Five samples of dark blue clay were collected from the London Brick Company's pit at Oxshott. They were obtained from a working-face of the pit at intervals of 6 ft.

Fifteen samples were collected from the Alum Bay exposure of the London Clay and as far as possible at regular intervals through the succession.

---

[1] Now demolished for new buildings in the course of construction.—*Ed.*

Ten samples were collected from the Whitecliff Bay exposure of the London Clay, five from the lowest 50 ft. of the succession, the remainder at regularly spaced intervals. In preparing the material, the samples were placed in open metal dishes and boiled in water. This was normally sufficient to disintegrate them, but if not, sodium carbonate or, in difficult cases, sodium hydroxide was added to facilitate this process. After repeated boiling and decanting, a small residue remained and this was dried and the Foraminifera and other organisms were removed by picking with a fine camel-hair brush. The inorganic residue usually comprises fine-grained quartz accompanied by varying amounts of muscovite, glauconite, felspar and fragments of flint. Heavy minerals, such as iron pyrites, magnetite, rutile and spinel may be present, while crystals of selenite are common. There is much variation in bulk in the residues.

4. IDENTIFICATION

Identification of the species recorded was carried out by comparing the specimens with holotypes or topotypes when these were available and with photographs or figures when they were not. In some cases, e.g., *Lenticulina rotulata* (Lamarck), the type figure was disregarded in favour of a more recent figure of the holotype (in this case by Cushman). The justification for this procedure lies in the unreliability of many of the figures drawn prior to this century. It was frequently found impossible to locate the holotypes of some species, the depositories being unknown, e.g., *Bulimina ovata* d'Orbigny. Investigation of the d'Orbigny material in the Natural History Museum in Paris, in 1951, revealed the difficulties involved in determining holotypes even when the depository is known.

The specimens were mounted in gum arabic on slips of glass (underlain by blue paper) and enclosed in a set of glass tubes cemented to boards bearing in manuscript the name and occasionally the locality of the enclosed specimen. According to Heron-Allen & Earland, this was done about 1892 and subsequent degeneration of the glass, fungoid decomposition of the calcareous tests and detachment of the specimens by expansion and contraction of the hygroscopic gum arabic have combined to render most of the material useless since it is unidentifiable with accuracy.

5. CLASSIFICATION

The classification adopted in the present work is substantially that proposed by J. A. Cushman (1948) in the revised and enlarged fourth edition of his text book. The modifications introduced by the author are stated below.

a. *Lenticulina* and *Robulus*. Cushman stated that 'in many species it is very difficult to separate *Robulus* from *Lenticulina* and it may be best as a practical matter to drop *Robulus* and use *Lenticulina* for both'. This has been done in the present work.

b. *Alabamina.* The systematic position of this genus has been altered. Cushman placed it in the *Cassidulinidae*, but as it retains so many rotaliid features and lacks the characteristic alternation of the chambers on two sides of the plane of coiling seen in specialised genera of this family, it seems better to the present author to retain *Alabamina* in the Rotaliidae.

c. *Spiroplectammina* and *Bolivinopsis.* The author agrees with Glaessner (1945) that the name *Spiroplectammina*, often applied to initially coiled textulariid species, must be replaced by *Bolivinopsis*, since Kalinin (1937) has shown that in the type species of *Bolivinopsis* (*B. capitata* Yakovlev, 1891), the wall is arenaceous.

6. SYSTEMATIC RECORD

The families are arranged in alphabetical order. Representative specimens of the species have been presented to the Trustees of the British Museum (Natural History).

Family: AMMODISCIDAE

Subfamily: AMMODISCINAE

Genus: AMMODISCUS Reuss, 1861

Ammodiscus finlayi Parr

1935. *Ammodiscus finlayi* Parr, *Trans. Proc. Roy. Soc. N.Z.*, **65**, 80, pl. 19, fig. 5.

Remarks. *Ammodiscus dominicensis* Bermudez var. *deformis* Bermudez (1949) resembles the present species, but has a relatively narrower outermost whorl and a more compressed test. One specimen (P. 41029)[1].

Ammodiscus incertus (d'Orbigny)

1839. *Operculina incerta* d'Orbigny, *in* Ramon de la Sagra, *Hist. Phys. et Nat. de l'Ile de Cuba*, 71, pl. 6, figs. 16, 17.

1889. *Ammodiscus incertus* (d'Orbigny) : Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, 485, pl. 11, fig. 7.

Remarks. The apertural region is broken in the single specimen available, but the numerous whorls of the second chamber are characteristic of the species. One specimen (P. 41030).

Ammodiscus sp.

Description. The test is poorly preserved in the single specimen available. It is sub-triangular in shape in plan view and moderately thick with biconcave cross-section. There are few whorls and the wall is finely arenaceous with little calcareous cement. The apertural region is obscure. One specimen (P. 41031).

---

[1] Numbers in brackets preceded by the letter P. indicate registration numbers in the collections of the British Museum (Natural History).

Family: ANOMALINIDAE

Subfamily: ANOMALININAE

Genus: **ANOMALINA** d'Orbigny, 1826

Anomalina flintii Cushman

1931. *Anomalina flintii* Cushman, *U.S. Nat. Mus. Bull. No.* 104, 108, pl. 18, fig. 5.
1949. *Anomalina flintii* Cushman: Bermudez, *Cush. Lab. For. Res., Sp. Pub. No.* 25, 289, pl. 22, figs. 41–3.

Remarks. There is nothing to add to the description given by Cushman (1931). Two specimens (P. 41032(1–2)).

Anomalina globulosa Chapman & Parr

1937. *Anomalina globulosa* Chapman & Parr, Australasian Antarctic Expedition 1911–14, *Sci. Reps.* (C), **1**, (2), 117, pl. 9, fig. 27.
1948. *Anomalina madrugaensis* Cushman & Bermudez, *Contr. Cush. Lab. For. Res.*, **24**, 86, pl. 15, figs. 4–6.

Remarks. *Anomalina granosa* (Hantken, 1875) resembles the present species, but is more compressed and lacks the markedly lobulate periphery characteristic of the latter.

Anomalina grosserugosa (Gümbel, 1868) differs from the present species in being wholly involute; in having more chambers in the last whorl and in being less close-coiled. Three specimens (P. 41033(1–3)).

Anomalina perthensis Parr

1938. *Anomalina perthensis* Parr, *Journ. Roy. Soc. W. Australia*, **24**, (8), 85, pl. 3, fig. 3.

Remarks. In his description of the holotype, Parr (1938) stated that up to twelve chambers may be present in the last whorl. The present specimen possesses eleven. One specimen (P. 41034).

Genus: **PLANULINA** d'Orbigny, 1826

Planulina anglica sp. nov.

Fig. A, 1–3

Diagnosis. The test is compressed, evolute dorsally and involute ventrally with nine or ten chambers in the last whorl separated by curved, limbate sutures which are slightly raised dorsally. There is a prominent, pitted umbilical boss on the dorsal side which obscures the inner whorls and a smaller smooth boss occurs on the ventral side. The test is slightly more convex ventrally than dorsally and the periphery is sub-acute and slightly lobulate. The low, curved aperture is situated at the base of the end chamber in a median position.

Remarks. *Planulina kniffeni* Howe (1939) resembles the present species, but has no ventral umbilical boss and more chambers in the last whorl. Holotype: P. 41035. Type level: Upper London Clay, Whitecliff Bay, Isle of Wight (Sample 7).

Subfamily: CIBICIDINAE

Genus: **CIBICIDELLA** Cushman, 1927

Cibicidella variabilis (d'Orbigny)

1826. *Truncatulina variabilis* d'Orbigny, *Ann. Sci. Nat.*, **7**, 279.
1927. *Cibicidella variabilis* (d'Orbigny): Cushman, *Contr. Cush. Lab. For. Res.*, **3**, 93.

Remarks. The author agrees with Bagg (1912) that this species is probably 'only an irregular type of *Truncatulina lobatula*'. Five specimens (P. 41036(1–5)).

Genus: **CIBICIDES** Montfort, 1808

There is some confusion in the literature regarding the use of the terms 'ventral' and 'dorsal' with respect to this genus. Samoilova (1947) agreed with Cushman that the evolute side should be regarded as dorsal and the involute as ventral. Plummer (1926) defined them to the contrary. The present author has adopted Cushman's usage.

Cibicides delicatus Le Roy

1944. *Cibicides delicatus* Le Roy, *Quart. Colorado School Mines*, Colorado, **39**, (3), 42, pl. 2, figs. 19–21.

Remarks. There is nothing to add to the description given by Le Roy (1944). One specimen (P. 41037).

Cibicides lobatulus (Walker & Jacob)

Fig. A, 4–6

1798. *Nautilus lobatulus* Walker & Jacob, *Adams's Essays*, *Kanmacher Edition*, 642, pl. 14, fig. 36.
1886. *Truncatulina lobatula* (Walker & Jacob): Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6**, 756, pl. 16, fig. 12.
1931. *Cibicides lobatula* (Walker & Jacob): Cushman, *U.S. Nat. Mus. Bull.*, 104, 118, pl. 21, fig. 3.
1949. *Cibicides lobatulus* (Walker & Jacob): Said, *Cush. Lab. For. Res.*, *Sp. Pub. No.* 26, 42, pl. 4, fig. 21.

Remarks. According to Brady (1884), this very variable species may intergrade with several others, e.g., *Cibicides boueana* (d'Orbigny, 1846), but the present author agrees with Marks (1951) that the latter can be distinguished by its uninflated chambers and much more curved ventral sutures. The similar species *Cibicides cookei* Cushman & Garrett (1938) differs from the present one in having the sutures limbate throughout.

Cibicides beatus Martin (1943) differs in possessing a well-developed keel. Three specimens (P. 41038(1–3)).

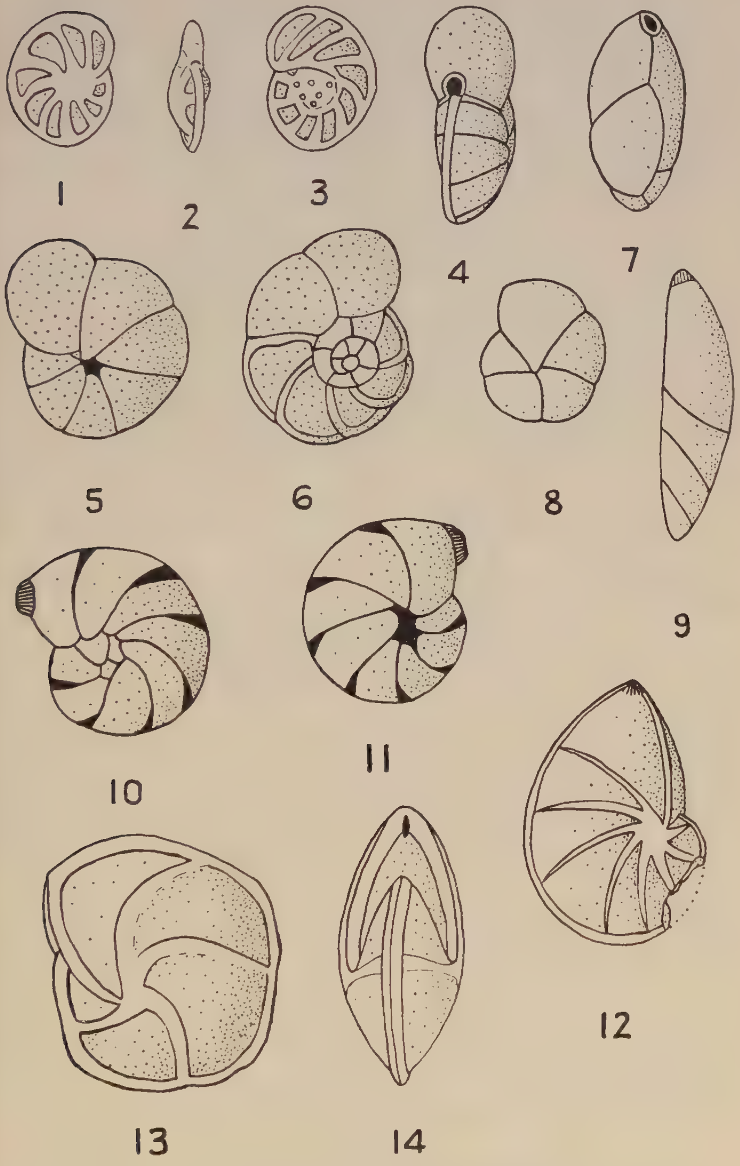


Fig. A. London Clay Foraminifera

Cibicides praecursorius (Schwager)

1883. *Discorbina praecursoria* Schwager, *Palaeontographica*, **30**, *Pal. Th.*, 125, pl. 27, (4), figs. 12, 13; pl. 29, (6), figs. 16a–16d.
1941. *Cibicides praecursorius* (Schwager): Toulmin, *Journ. Paleont.*, **15**, 610, pl. 82, figs. 19–21.

Remarks. *Cibicides celebrus* Bandy (1944) resembles the present species, but is less compressed and has a papillate dorsal umbo.

Cibicides cushmani Nuttall (1930) differs in having a depressed ventral umbilical region. Two specimens (P. 41039(1–2)).

Cibicides pseudoungerianus (Cushman)

1922. *Truncatulina pseudoungeriana* Cushman, *U.S. Geol. Surv. Prof. Paper No.* 129, 97, 136, pl. 20, fig. 9.
1949. *Cibicides pseudoungerianus* (Cushman): Bermudez, *Cush. Lab. For. Res., Sp. Pub. No.* 25, 304, pl. 24, figs. 28–30.

Remarks. *Cibicides trincherasensis* Bermudez (1949) closely resembles the present species, but has fewer chambers in the last whorl and a limbate spiral suture on the evolute side. Two specimens (P. 41040(1–2)).

Cibicides pygmeus (Hantken) var. **almaensis** Samoilova

1947. *Cibicides pygmeus* (Hantken) var. *almaensis* Samoilova, *Soc. Nat. Moscow Bull.*, Moscow, (N.S.), **52**, (Sect. Geol., **22**), No. 4, 94 [Russian], 101 [English].

Remarks. Great variation in the convexity of the dorsal side is shown in this variety. One specimen (P. 41041).

Cibicides vulgaris (Plummer)

1926. *Truncatulina vulgaris* Plummer, *Texas Univ. Bull. No.* 2644, 145, pl. 10, fig. 3.

Description. There are nine chambers in the last whorl separated by slightly curved sutures which on both sides are initially slightly elevated and strongly limbate, later becoming slightly depressed and non-limbate. Plummer (1926) stated that this species varies in the degree of development of the limbations, some specimens having well-marked spirals of calcareous material on each side.

Remarks. *Cibicides alleni* (Plummer, 1926) differs from the present species only in having more chambers in the last whorl. Two specimens (P. 41042(1–2)).

Family: BULIMINIDAE

Subfamily: BULIMININAE

Genus: **BULIMINA** d'Orbigny, 1826

Bulimina ovata d'Orbigny

Fig. A, 7

1846. *Bulimina ovata* d'Orbigny, *For. Foss. Bass. Tert. Vienne*, 185, pl. 11, figs. 13, 14.

1946. *Bulimina sp. A*, Detling, *Journ. Paleont.*, **20**, 356, pl. 50, fig. 1.
1951. *Bulimina ovata* d'Orbigny: Cushman & Stainforth, *Journ. Paleont.*, **25**, 151, pl. 26, fig. 44.

Remarks. Various authors have commented on the difficulty of separating this species from the many others which resemble it. Parker & Jones (1865) stated that it is 'almost identical' with *Bulimina pupoides* d'Orbigny (1846) and regarded it as probably a variety of the latter. The present author agrees with Cushman (1932) that these two species are distinct. The present species has a more oval test and a relatively longer last whorl of chambers than *B. pupoides*.

The following species closely resemble the present one, but can be distinguished by the characters stated.

Bulimina debilis Martin (1943) has squarer chambers and an apertural lip; *Bulimina guayabalensis* Cole (1927) has fewer and differently arranged chambers; *Bulimina marginospinata* Cushman & Parker (1938) has short spines at the basal margins of the chambers, and *Bulimina rotundata* Hussey (1949) possesses an apertural plate half concealing the aperture. Three specimens (P. 41043(1–3)).

Bulimina ovula d'Orbigny

1839. *Bulimina ovula* d'Orbigny, *For. Amer. Merid.*, **5**, (5), 51, pl. 1, figs. 10, 11.

Remarks. *Bulimina ariminensis* d'Orbigny (1826) closely resembles the present species, but is relatively longer with more chambers visible. One specimen (P. 41044).

Subfamily: UVIGERININAE

Genus: **UVIGERINA** d'Orbigny, 1826

Uvigerina aculeata d'Orbigny var. **asperula** Czjzek

1847. *Uvigerina asperula* Czjzek, *in* Haidinger's *Nat. Abh.*, **2**, 146, pl. 13, figs. 14, 15.
1886. *Uvigerina asperula* Czjzek : Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6**, 755, pl. 16, fig. 7.

Description. The wall is finely spinose. Cushman & Edwards (1939) stated that this variety has many of the characteristics of *U. aculeata* and 'probably represents one of the variations'. Czjzek's type figure is 'much conventionalised' and the spines are illustrated as much finer than they are.

Remarks. *Uvigerina orbignyana* Czjzek (1847), possibly another variant of *U. aculeata* according to Cushman & Edwards (1939), differs from the present variety in having more inflated chambers. Four specimens (P. 41045(1–4)).

Uvigerina canariensis d'Orbigny

1839. *Uvigerina canariensis* d'Orbigny, *For. Can.*, 138, pl. 1, figs. 25–27.

1932. *Uvigerina canariensis* d'Orbigny: Heron-Allen & Earland, *Discovery Reps.*, **4,** 395.

Remarks. There is nothing to add to previous descriptions. One specimen (P. 41046).

Uvigerina jacksonensis Cushman

1925. *Uvigerina jacksonensis* Cushman, *Contr. Cush. Lab. For. Res.*, **1,** 67, pl. 10, fig. 13.

Description. The wall of the test is ornamented by prominent longitudinal costae which are initially limited to the individual chamber and later tend to become confluent with those of the chambers above and below. The number of costae varies from eighteen to twenty-two on the circumference of the widest part of the test.

Remarks. *Uvigerina mediterranea* Hofker (1932) resembles the present species, but can be distinguished by its relatively greater length, more numerous costae and less prominent apertural neck. One specimen (P. 41047).

Uvigerina pigmea d'Orbigny

1826. *Uvigerina pigmea* d'Orbigny, *Ann. Sci. Nat.*, **7,** 269, pl. 12, figs. 8, 9.
1932. *Uvigerina pygmaea* d'Orbigny: Nuttall, *Journ. Paleont.*, **6,** 21, pl. 5, fig. 6.
1949. *Uvigerina pigmaea* d'Orbigny : Bermudez, *Cush. Lab. For. Res.*, *Sp. Pub. No.* 25, 209, pl. 13, fig. 44.

Remarks. Flint (1897) assigned specimens to the present species which were subsequently placed by Cushman in *Uvigerina peregrina* Cushman (1923). Heron-Allen & Earland (1932) included the latter in the synonymy of the present species. The present author regards the two species as distinct. Cushman (1923) stated that the costae in his species are high and plate-like with granular surfaces. One specimen (P. 41048).

Subfamily: VIRGULININAE

Genus: **BOLIVINA** d'Orbigny, 1839

Bolivina advena Cushman

1925. *Bolivina advena* Cushman, *Contr. Cush. Lab. For. Res.*, **1,** 29, pl. 5, fig. 1.

Remarks. There is nothing to add to the previous description. One specimen (P. 41049).

Bolivina moodysensis Cushman & Todd

1945. *Bolivina moodysensis* Cushman & Todd, *Contr. Cush. Lab. For. Res.*, **21,** 97, pl. 15, figs. 19, 20.

Remarks. This species has some features in common with *Bolivina calvertensis* Dorsey (1948), but can be distinguished by its being more compressed and having the longitudinal costae confined to the initial part of the test. Four specimens (P. 41050(1–4)).

Bolivina punctata d'Orbigny

1839. *Bolivina punctata* d'Orbigny, *For. Amer. Merid.*, 63, pl. 8, figs. 10–12.
1886. *Bolivina punctata* d'Orbigny: Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6,** 743, pl. 14, fig. 10.

Remarks. Although Brady (1884) stated that this species is closely similar to *Bolivina antiqua* d'Orbigny (1846) and regarded the differences between them as insufficient to justify separating them, the present author considers that they are distinct. *B. antiqua* is a relatively narrower form with much more oblique sutures. Five specimens (P. 41051(1–5)).

Family: CHILOSTOMELLIDAE

Subfamily: ALLOMORPHINELLINAE

Genus: **PULLENIA** Parker & Jones, 1862

Pullenia bulloides (d'Orbigny)

1826. *Nonionina bulloides* d'Orbigny, *Ann. Sci. Nat.*, **7,** 293.
1949. *Pullenia bulloides* (d'Orbigny): Bermudez, *Cush. Lab. For. Res., Sp. Pub. No.* 25, 276, pl. 21, figs. 28, 29.

Remarks. *Pullenia subsphaerica* Parr (1950) resembles the present species, but is slightly compressed in apertural view. One specimen (P. 41052).

Pullenia quinqueloba (Reuss)

Fig. A, 8

1851. *Nonionina quinqueloba* Reuss, *Zeitschr. d. deutsch. Geol. Ges.*, **3,** 71, pl. 5, fig. 31.
1889. *Pullenia quinqueloba* (Reuss): Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, 487, pl. 11, fig. 29.
1950. *Pullenia quinqueloba* (Reuss): Nakkady, *Journ. Paleont.*, **24,** 682.

Remarks. *Pullenia compressa* Seguenza (1879) resembles the present species, but is much more compressed in apertural view. Three specimens (P. 41053(1–3)).

Pullenia quinqueloba (Reuss) var. **quadriloba** Reuss

1867. *Pullenia compressiuscula* Reuss var. *quadriloba* Reuss, *Sitz. Akad. Wiss. Wien*, **55,** 87, pl. 3, fig. 8.
1943. *Pullenia quadriloba* (Reuss): Cushman & Todd, *Contr. Cush. Lab. For. Res.*, **19,** 15, pl. 2, figs. 20, 21.

Remarks. Reuss (1866) replaced his original name *Nonionina quinqueloba* 1851 by *Pullenia compressiuscula* as a result of his discovery of four-chambered forms identical with *P. quinqueloba* in all but the number of chambers. He called the four-chambered forms *P. compressiuscula* var. *quadriloba*. This action was not correct under the International Rules of Zoological Nomenclature, hence the original name is the valid, and the present variety is properly *P. quinqueloba* var. *quadriloba*. One specimen (P. 41054).

Pullenia salisburyi R. E. & K. C. Stewart

1930. *Pullenia salisburyi* R. E. & K. C. Stewart, *Journ. Paleont.*, **4,** 72, pl. 8, fig. 2.
1945. *Pullenia salisburyi* R. E. & K. C. Stewart: Cushman & Ellisor, *Journ. Paleont*, **19,** 570, pl. 78, fig. 5.

Remarks. This species can be distinguished from *P. quinqueloba* by its greater degree of compression and six chambers in the last whorl. Two specimens (P. 41055(1–2)).

Pullenia trinitatensis Cushman & Stainforth

1945. *Pullenia trinitatensis* Cushman & Stainforth, *Cush. Lab. For. Res., Sp. Pub. No.* 14, 66, pl. 12, fig. 11.

Remarks. *Pullenia malkinae* Coryell & Mossman (1942) resembles the present species, but can be distinguished by its rounded periphery and lipped aperture. Two specimens (P. 41056(1–2)).

Subfamily: CHILOSTOMELLINAE

Genus: **CHILOSTOMELLOIDES** Cushman, 1926

Chilostomelloides oviformis (Sherborn & Chapman)

1886. *Lagena* (*Obliquina*) *oviformis* Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6,** 745, pl. 14, fig. 19.
1889. *Chilostomella oviformis* Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, 485, pl. 11, fig. 13.
1889. *Chilostomella ovoidea* Reuss: Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, 485, pl. 11, fig. 12.
1949. *Chilostomelloides oviformis* (Sherborn & Chapman), Bermudez, *Cush. Lab. For. Res., Sp. Pub. No.* 25, 275, pl. 21, figs. 22–24.

Remarks. The notch in the upper apertural lip of this species noted by Sherborn & Chapman (1886) does not occur in any specimen examined by the author, including those deposited by these authors in the British Museum (Natural History). Examination of the Sherborn & Chapman material showed that the specimen figured by them (1889) as *Chilostomella ovoidea* Reuss (P. 4401) is identical with the present species in all but size. It is smaller with a slightly less prominent apertural protuberance and, in the opinion of the author, is an immature specimen of *C. oviformis*. One specimen (P.41057).

Family: GLOBIGERINIDAE

Subfamily: GLOBIGERININAE

Genus: **GLOBIGERINA** d'Orbigny, 1826

Globigerina bulloides d'Orbigny

1826. *Globigerina bulloides* d'Orbigny, *Ann. Sci. Nat.*, **7,** 277.
1886. *Globigerina bulloides* d'Orbigny: Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6,** 756, pl. 16, fig. 8.

Remarks. Examination of the literature shows that many of the specimens figured under this specific name are wrongly identified. The closely similar species *Globigerina pseudobulloides* Plummer (1926) differs only in possessing an apertural lip. Three specimens (P. 41058(1–3)).

Globigerina dubia Egger

1857. *Globigerina dubia* Egger, *Neues Jahrb. f. Min.*, 281, pl. 9, figs. 7–9.
1901. *Globigerina eggeri* Rhumbler, *in* Brandt, *Nordisches Plankton*, Kiel, **1**, (14), 19.
1950. *Globigerina dubia* Egger: Wiseman & Ovey, *Proc. Geol. Assoc.*, **61**, 67, pl. 3, fig. 10.

Remarks. The only difference recorded by Rhumbler (1901) between *G. dubia* and *G. eggeri* is that of size, but this is not significant in the opinion of the present author. Halkyard (1919) recorded unusually small specimens of the former and Heron-Allen & Earland, in their comments, stated that they 'evidently existed under extremely unfavourable conditions'. Three specimens (P. 41059(1–3)).

Globigerina triloculari**s** d'Orbigny

1826. *Globigerina trilocularis* d'Orbigny, *Ann. Sci. Nat.*, **7**, 277.

Remarks. There is nothing to add to the previous descriptions of this species. One specimen (P. 41060).

Subfamily: ORBULININAE

Genus: **ORBULINA** d'Orbigny, 1839

Orbulina universa d'Orbigny

1839. *Orbulina universa* d'Orbigny, *in* Ramon de la Sagra, *Hist. Nat. Phys. de l'Ile de Cuba*, 3, pl. 1, fig. 1.
1886. *Orbulina universa* d'Orbigny: Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6**, 756, pl. 16, fig. 9.

Remarks. There is some confusion in the literature regarding the range of this species. Le Roy (1943) affirmed that it first appeared in the Miocene, but later (1948) admitted its occurrence in the Oligocene. This latter view was also taken by Bermudez (1949), who stated that it 'has not been observed in samples older than Middle Oligocene'. On the other hand, Beck (1943), Halkyard (1919), Sherborn & Chapman (1886) and the present author have all recorded the species from deposits of Eocene age and Williams-Mitchell (1948) noted it in the Chalk. There can be little doubt that, in fact, it ranges throughout the Tertiary. Four specimens (P. 41061 (1–4)).

Family: GLOBOROTALIIDAE

Genus: **GLOBOROTALIA** Cushman, 1927

Globorotalia boueana (d'Orbigny)

1846. *Rotalina boueana* d'Orbigny, *For. Foss. Bass. Tert. Vienne*, 152, pl. 7, figs. 25–7.

1886. *Pulvinulina boueana* (d'Orbigny): Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6**, 758, pl. 16, fig. 20.

Remarks. Several authors, e.g., Marks (1951), considered this species to be identical with *Globorotalia menardii* (d'Orbigny, 1826), but the present author regards them as distinct. The present species is more evolute dorsally with a greater number of chambers in the last whorl and a more prominent keel. Four specimens (P. 41062(1–4)).

Family: HETEROHELICIDAE

Subfamily: EOUVIGERININAE

Genus: **NODOGENERINA** Cushman, 1927

Nodogenerina hirsuta (Soldani)

1799. *Nodosaria hirsuta* Soldani, *Test.*, **4**, tab. 2, fig. P.
1886. *Nodosaria hispida* d'Orbigny: Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6**, 748, pl. 14, fig. 32.
1951. *Nodogenerina hirsuta* (Soldani): Marks, *Contr. Cush. Found. For. Res.*, **2**, 56, pl. 7, fig. 7.

Remarks. There is nothing to add to the description given by Marks (1951). Two specimens (P. 41063(1–2)).

Subfamily: PLECTOFRONDICULARIINAE

Genus: **ORTHOMORPHINA** Stainforth, 1952

Orthomorphina ambigua (Neugeboren)

1856. *Nodosaria ambigua* Neugeboren, *K. Akad. Wiss. Wien, Math.–Nat. Cl.*, **12**, 71, pl. 1, figs. 13–16.
1889. *Nodosaria radicula* (Linné) var. *ambigua* Neugeboren: Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, 486, pl. 11, fig. 16.
1952. *Orthomorphina ambigua* (Neugeboren): Stainforth, *Contr. Cush. Found. For. Res.*, **3**, 8.

Remarks. There is nothing to add to previous descriptions. One specimen (P. 41064).

Family: LAGENIDAE

Subfamily: LAGENINAE

Genus: **LAGENA** Walker & Jacob, 1798

Lagena globosa (Montagu)

1803. *Vermiculum globosum* Montagu, *Test. Brit.*, 523.
1886. *Lagena globosa* (Montagu): Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6**, 744, pl. 14, fig. 11.
1932. *Lagena globosa* (Montagu): Heron-Allen & Earland, *Discovery Reps.*, **4**, 361.

Remarks. This is a very variable species and may be globular or subglobular, thin or thick walled with simple or radiate aperture. One specimen (P. 41065).

Lagena hexagona (Williamson)

1848. *Entosolenia squamosa* (Montagu) var. *hexagona* Williamson, *Ann. Mag. Nat. Hist.*, (2), **1,** 20, pl. 2, fig. 23.
1919. *Lagena reticulata* Macgillivray: Halkyard, *Manch. Mem.*, **62,** 60.
1919. *Lagena melo* d'Orbigny: Halkyard, *Manch. Mem.*, **62,** 60.
1949. *Lagena hexagona* (Williamson): Bermudez, *Cush. Lab. For. Res., Sp. Pub. No.* 25, 117.

Remarks. *Lagena seminuda* Brady (1884) can only be distinguished from the present species by the smooth terminal part of the test, the similar ornament being confined to the initial end. Two specimens (P. 41066(1–2)).

Lagena laevis (Montagu)

1803. *Vermiculum laeve* Montagu, *Test. Brit.*, 524.
1886. *Lagena laevis* (Montagu): Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6,** 744, pl. 14, fig. 13.

Remarks. The long, tubular neck distinguishes this species from *L. globosa*. Two specimens (P. 41067(1–2)).

Lagena oxystoma Reuss

1858. *Lagena oxystoma* Reuss, *Zeitschr. d. deutsch. Geol. Ges.*, **10,** 433.
1886. *Lagena vulgaris* (Williamson) var. *oxystoma* Reuss: Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6,** 744, pl. 14, fig. 15.

Remarks. *Lagena hystrix* Reuss (1863) resembles the present species, but has a more prominent and spinose ornament. One specimen (P. 41068).

Lagena salinensis Howe

1939. *Lagena salinensis* Howe, *Louisiana Dept. Conserv., Geol. Surv. Bull. No.* 14, 51, pl. 6, fig. 14.

Description. The neck has a well-marked ornament of eight rings of calcareous material along its length.

Remarks. The ornament distinguishes this species from *L. laevis*. One specimen (P. 41069).

Lagena sphaeroidalis (Fornasini)

1894. *Oolina sphaeroidalis* Fornasini, *R. Accad. Sci. Inst. Bologna, Mem. Sci. Nat.*, (5), **4,** 223.

Description. The test is smooth and spherical with the round aperture placed at the end of a slight neck. One specimen (P. 41070).

Lagena striata (d'Orbigny)

1839. *Oolina striata* d'Orbigny, *For. Amer. Merid.*, 21, pl. 5, fig. 12.
1886. *Lagena striata* (d'Orbigny): Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6,** 745, pl. 14, figs. 16, 17.

Description. The species is very variable in shape, ranging from globular to pear-shaped. The surface is ornamented by a number of costae which vary from twenty-four to thirty-four in the region of maximum circumference. Usually there is a terminal neck with the round aperture at the end of it. When present, the neck may be long or short and is sometimes ornamented by a series of rings of calcareous matter placed at regular intervals along it, or a number of oblique striae may occur. When the neck is absent, the test is pear-shaped with the aperture at the tapering end.

Remarks. *Lagena substriata* Williamson (1848) resembles the present species, but differs in having a lipped aperture. One specimen (P. 41071).

Lagena sulcata (Walker & Jacob)

1798. *Serpula* (*Lagena*) *sulcata* Walker & Jacob, *Adams's Essays, Kanmacher Ed.*, 634, pl. 14, fig. 5.
1886. *Lagena sulcata* (Walker & Jacob): Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6**, 745, pl. 14, fig. 18.
1949. *Lagena sulcata* (Walker & Jacob): Bermudez, *Cush. Lab. For. Res., Sp. Pub. No.* 25, 118, pl. 10, fig. 48.

Description. The costae are variable in number, sixteen being present on the deposited specimen.

Remarks. Heron-Allen & Earland (1932) believed that 'many *striatas* may be assigned to weak *sulcatas*' and Bagg (1912) pointed out that 'reduction of the striations and deepening of the zones between them gives rise to sulcate types'. The present species may be distinguished from *L. striata*, however, despite the similarity in shape and variability in numbers and prominence of costae. The numbers range from fourteen to eighteen in the present form whereas in *L. striata* there are always more and finer costae ranging from twenty-four to thirty-four in number. One specimen (P. 41072).

Subfamily: NODOSARIINAE

Genus: **DENTALINA** d'Orbigny, 1826

Dentalina bradyensis (Dervieux)

1894. *Nodosaria inornata* (d'Orbigny) var. *bradyensis* Dervieux, *Bull. Soc. Geol. Ital.*, **12**, 610, pl. 5, figs. 30, 31.

Remarks. This species differs from *Dentalina communis* d'Orbigny (1826) in being relatively stouter with smaller proloculum. One specimen (P. 41073).

Dentalina multilineata Bornemann

1855. *Dentalina multilineata* Bornemann, *Zeitschr. d. deutsch. Geol. Ges.*, **7**, 325, pl. 13, fig. 12.
1886. *Dentalina multilineata* Bornemann: Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6**, 751, pl. 15, fig. 14.

Two specimens (P. 41074(1–2)).

Dentalina obliquata Reuss

1863. *Nodosaria* (*Dentalina*) *obliquata* Reuss, *K. Akad. Wiss. Wien, Math.–Nat. Cl.*, **48**, 46, pl. 2, fig. 25.

One specimen (P. 41075).

Dentalina pauperata d'Orbigny

1846. *Dentalina pauperata* d'Orbigny, *For. Foss. Bass. Tert. Vienne,* 46, pl. 1, figs. 57, 58.
1886. *Dentalina pauperata* d'Orbigny: Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6,** 750, pl. 15, fig. 9.
1949. *Dentalina pauperata* d'Orbigny: Bermudez, *Cush. Lab. For. Res., Sp. Pub. No.* 25, 144, pl. 9, fig. 45.

Remarks. The present species always occurs in the megalospheric form and is probably identical with *Dentalina verneuili* d'Orbigny (1846), this latter, which always occurs in the microspheric form, represents the alternate generation. Three specimens (P. 41076(1–3)).

Dentalina sherborni sp. nov.

Fig. A, 9

1886. *Vaginulina legumen* (Linné): Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6,** p. 753, pl. 15, fig. 19.
1889. *Vaginulina sp.*: Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, 486, pl. 11, fig. 25.

Diagnosis. The test is elongate, rectilinear or slightly curvilinear, with one side nearly or quite straight and the other convex. The initial end is acuminate and there are usually six chambers in the test separated by slightly depressed sutures which are markedly oblique to the longitudinal axis, becoming less so terminally. The end chamber is much larger than those which precede it. The wall is smooth and the radiate aperture is placed at the end of the last chamber.

Remarks. Examination of the specimens named *Vaginulina sp.* (P. 4392) and *Vaginulina legumen* (Linné) (P. 3666) by Sherborn & Chapman (1886; 1889) shows that their figures were not accurate and that these specimens in fact belong to this species. The suggestion of these authors that their *Vaginulina* sp. is deformed is invalidated by the large number of specimens recorded by the present author which show similar characters. Holotype: P. 41077. Type level: Enborne Bore 38: Depth 120 ft.

Genus **LENTICULINA** Lamarck 1804

Lenticulina articulata (Reuss)

Fig. A, 10, 11

1863. *Cristellaria* (*Robulina*) *articulata* Reuss, *Sitzb. K. Ak. Wiss. Wien Math.–Nat. Cl.* **48,** 53, pl. 5, fig. 62.
1936. *Cristellaria articulata* Reuss: Palmer & Bermudez, *Mem. Soc. Cubana Hist. Nat.*, **10,** 249.

Remarks. Brady (1884) regarded the present species as a 'thick variety of *Cristellaria rotulata*', an opinion with which the author does not agree. Three specimens (P. 41078(1–3)).

Lenticulina cushmani (Galloway & Wissler) var. **procedenus** Coryell & Mossman

1942. *Robulus cushmani* Galloway & Wissler var. *procedenus* Coryell & Mossman, *Journ. Paleont.*, **16**, 234, pl. 36, figs. 1, 2.

One specimen (P. 41079).

Lenticulina degolyeri (Plummer)

1926. *Cristellaria degolyeri* Plummer, *Bull. Univ. Texas, No.* 2644, 97, pl. 7, fig. 7.
1941. *Lenticulina degolyeri* (Plummer): Toulmin, *Journ. Paleont.*, **15**, 580, pl. 78, figs. 29, 30.

Description. The seven chambers of the last whorl are separated by curved sutures which are raised above the surface of the test; the last two are less prominently raised than the earlier ones. The aperture is radiate with a narrow slit on the apertural face of the end chamber. One specimen (P. 41080).

Lenticulina ellisori sp. nov.

Fig. A, 12

1933. *Robulus propinquus* Hantken: Ellisor, *Bull. Amer. Assoc. Petrol. Geol.*, **17**, (2), 1320, pl. 7, fig. 12.

Diagnosis. The planispiral, involute test is equally biconvex with eight chambers in the last whorl separated by slightly curved, flush sutures. The wall is smooth and the apertural face of the end chamber is convex. The radiate aperture is situated at the outer margin of the end chamber. Holotype: P. 41081. Type level: Upper London Clay, Whitecliff Bay, Isle of Wight (Sample 7).

Lenticulina flexuosa (Sherborn & Chapman)

Fig. A, 13, 14

1886. *Cristellaria rotulata* (Lamarck) var. *flexuosa* Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6**, 754, pl. 15, fig. 26.

Description. The planispiral test is sub-quadrate in plan view, biconvex in apertural view, involute with five chambers in the last whorl separated by curved, flush, limbate sutures. There is a thin, prominent keel and the aperture is situated at the outer margin of the end chamber. It is radiate with a slit on the apertural face of the end chamber.

Remarks. Sherborn & Chapman (1886) referred to this species as 'strongly waved or flexed in the line of growth giving the shell a contorted appearance', and stated that no external septation can be seen. The keel is considered 'almost obsolete'. Examination of the present specimens and of the holotype at the British Museum (Natural History) (P. 3691) showed that none of these assertions is accurate and the type figure is badly drawn and does not convey the morphological characters at all clearly. One specimen (P. 41082).

Lenticulina gibba (d'Orbigny)

1839. *Cristellaria gibba* d'Orbigny, *in* Ramon de la Sagra, *Hist. Phys. Nat. de l'Ile de Cuba*, 40, pl. 7, figs. 20, 21.
1946. *Robulus gibba* (d'Orbigny): Colom, *Bull. Inst. Geol. Lucas Mallada, No.* 3, 67, pl. 8, fig. 194.
1949. *Robulus gibbus* (d'Orbigny): Bermudez, *Cush. Lab. For. Res., Sp. Pub. No.* 25, 126, pl. 7, figs. 53, 54.

Two specimens (P. 41083(1–2)).

Lenticulina inornata (d'Orbigny)

1846. *Robulina inornata* d'Orbigny, *For. Foss. Bass. Tert. Vienne*, 102, pl. 4, figs. 25, 26.
1943. *Robulus inornatus* (d'Orbigny): Beck, *Journ. Paleont.*, **17**, 595, pl. 104, figs. 3, 4.

Remarks. Marks (1951) regarded the present species as a variant of *L. intermedius* (d'Orbigny, 1846), but the present author regards them as distinct. One specimen (P. 41084).

Lenticulina limbosa (Reuss)

1863. *Cristellaria* (*Robulina*) *limbosa* Reuss, *Sitzb. K. Ak. Wiss. Wien, Math.–Nat. Cl.*, **48**, 55, pl. 6, fig. 69.
1939. *Robulus limbosus* (Reuss): Cushman, *Contr. Cush. Lab. For. Res.*, **15**, 52, pl. 9, fig. 20.

Description and remarks. An involute species with from eight to twelve chambers in the last whorl and thin, very prominent keel. The aperture is situated at the outer margin of the end chamber and is radiate with a narrow slit extending on to the apertural face of this chamber.

In the author's opinion, the present species has been frequently recorded under the trivial name '*cultrata*', which was the usual designation applied to forms with thin, well-developed keels during the nineteenth century. Specimens so named are deposited in the British Museum (Natural History) in the Parker Collection of Foraminifera from the London Clay and they are closely similar to the present specimens. The nature of *L. cultrata* (Montfort, 1808) is indeterminate because of the unreliability of the type figure and the unavailability of the holotype. Two specimens (P. 41085 (1–2)).

Lenticulina mayi (Cushman & Parker)

1931. *Robulus mayi* Cushman & Parker, *Contr. Cush. Lab. For. Res.*, **7**, 2, pl. 1, figs. 3–5.

Remarks. The aperture is radiate and may or may not possess a slit on the apertural face of the end chamber. One specimen (P. 41086).

Lenticulina megalopolitana (Reuss)

1855. *Robulina megalopolitana* Reuss, *Zeitschr. d. deutsch. Geol. Ges.*, **7**, 272, pl. 9, fig. 5.
1886. *Cristellaria megalopolitana* (Reuss): Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6**, 755, pl. 15, fig. 30.

Remarks. The figure of this species given by Sherborn & Chapman (1886) is inaccurate. Examination of their specimen at the British Museum (Natural History) (P. 3685) showed that it has eight chambers in the last whorl, not seven as illustrated. One specimen (P. 41087).

Lenticulina navis (Bornemann)

1855. *Robulina navis* Bornemann, *Zeitschr. d. deutsch. Geol. Ges.*, **7**, 338.

One specimen (P. 41088).

Lenticulina rotulata (Lamarck)

1806. *Lenticulites rotulata* Lamarck, *Ann. Mus.*, **8**, 188, pl. 62, fig. 11.
1927. *Lenticulina rotulata* (Lamarck): Cushman, *Contr. Cush. Lab. For. Res.*, **3**, 124, pl. 28, fig. 7.

Remarks. This species was first recorded by Velin in 1802, but the earliest published figure and description are those of Lamarck (1806). The specimens examined by Lamarck were obtained from Meudon, Paris, and their geological age is in doubt, some authors, e.g., Glaessner (1945), placing them in the Upper Cretaceous, others, e.g., Cushman (1926), placing them in the Eocene. A further difficulty with the species is that the type figure and description are both inaccurate and inadequate for purposes of identification. Cushman refigured the type specimen in 1927 and this figure corresponds closely with the present specimens. One specimen (P. 41089).

Lenticulina splendens (Sherborn & Chapman)

1886. *Cristellaria cultrata* (Montfort) var. *splendens* Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6**, 755, pl. 15, fig. 29.

One specimen (P. 41090).

Lenticulina texanus (Cushman & Applin)

1926. *Cristellaria articulata* Reuss var. *texana* Cushman & Applin, *Bull. Amer. Assoc. Petrol. Geol.*, **10**, 170, pl. 8, figs. 1, 2.
1948. *Robulus texanus* (Cushman & Applin): Rau, *Journ. Paleont.*, **22**, 163, pl. 29, figs. 16, 17.

One specimen (P. 41091).

Lenticulina umbonata (Reuss)

1851. *Robulina umbonata* Reuss, *Zeitschr. d. deutsch. Geol. Ges.*, **3**, 68, pl. 4, fig. 24.

Description and remarks. This species is characterised by its prominent circular, raised, flat umbonal areas. There is a distinct keel and seven chambers in the last whorl separated by slightly curved, oblique sutures flush with the surface of the test. The wall is smooth and the radiate aperture is situated at the outer margin of the end chamber. *Lenticulina trigonostoma* (Reuss, 1851) is closely similar, but has less pronounced umbonal areas, more chambers in the last whorl and a more prominent keel. One specimen (P. 41092).

Lenticulina washingtonensis Beck

1943. *Lenticulina washingtonensis* Beck, *Journ. Paleont.*, **17**, 597, pl. 104, figs. 18, 21.

Description and remarks. The most characteristic feature is the great breadth in apertural view. There are four chambers in the last whorl and the ultimate three are almost equal in size. The radiate aperture lies at the outer margin of the end chamber. *Lenticulina crassa* (d'Orbigny, 1846) resembles the present species, but has only three chambers in the last whorl and a slit on the apertural face of the end chamber. *Lenticulina navis* (Bornemann, 1855) is much more compressed. One specimen (P. 41093).

Genus: **MARGINULINA** d'Orbigny, 1826

Marginulina crepidula (Fichtel & Moll)

1803. *Nautilus crepidula* Fichtel & Moll, *Test. Micr.*, 107, pl. 19, figs. *g–i*.
1886. *Cristellaria crepidula* (Fichtel & Moll): Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6**, 753, pl. 15, fig. 21.
1949. *Marginulina crepidula* (Fichtel & Moll): Bermudez, *Cush. Lab. For. Res., Sp. Pub. No.* 25, 139, pl. 9, figs. 22, 23.

Remarks. The closely similar species *Marginulina crepiduliformis* Bermudez (1949) is broader with inflated chambers. One specimen (P. 41094).

Marginulina enbornensis sp. nov.

Fig. B, 1–4

1886. *Marginulina wetherellii* Jones: Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6**, 752, pl. 15, fig. 18.
1918. *Cristellaria wetherellii* (Jones): Cushman, *Bull. U.S. Geol. Surv. No.* 676, 52.

Diagnosis. The test is planispirally coiled, later uncoiling, adopting rectilinear form with oval transverse section. There are usually nine chambers increasing in height progressively towards the apertural end, separated by slightly curved sutures and becoming inflated terminally. The test is highly ornamented and this ornament shows great variation. Sometimes the sutures are flush, but they may be ridged or raised into a series of distinct tubercles which may be long or short. The test may have complex arrangements of fine to coarse parallel costae running longitudinally. These are not always present, and when they are, they become less prominent aperturally. In the end and sometimes in the penultimate chambers, they are replaced by granular tuberculations which may be very fine on the aper-

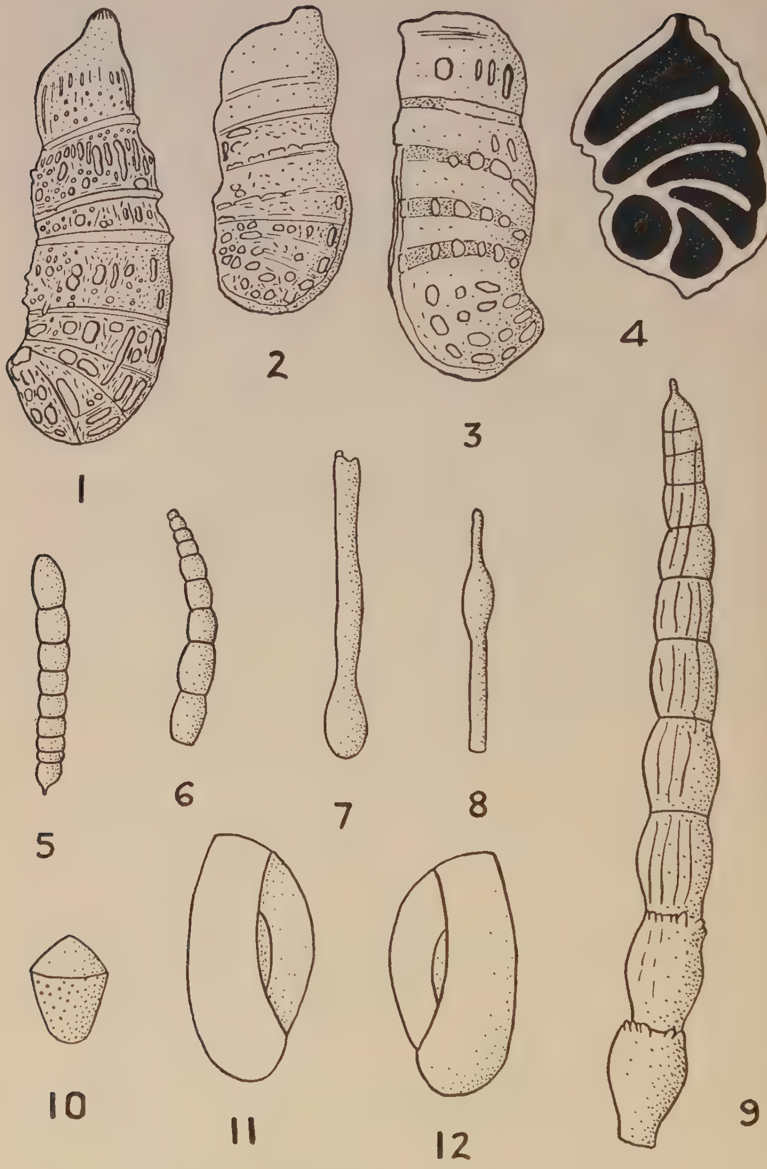


Fig. B. London Clay Foraminifera

tural chamber. If costae are absent, the only chamber ornament may be these tuberculations, which again grow finer aperturally until the last chamber has a hispid appearance. The periphery is not lobulate, but rough due to the heavy ornament. The aperture is eccentric on a distinct, stout neck on the end chamber. It is rounded and surmounted by a chamberlet with a radiate opening. As this chamberlet is frequently broken away, the aperture may appear round or radiate.

Remarks. This very common species has usually been assigned to *Marginulina wetherellii* Jones (1852), but examination of Jones's original specimens at the British Museum (Natural History) showed that this identification is incorrect. These latter are of Thanetian age and are labelled *Cristellaria italica* (Defrance) var. *wetherellii* Jones. There were eight specimens on the mounting card, but two of them are now lost. The remaining six do not match the type figure and the holotype was probably one of those lost. Examination of those now present showed two planispirally coiled, smooth forms with eight chambers each in the last whorl of the involute test (these may be young forms), and four uncoiling specimens which are incomplete, with the apertural chamber missing in all. Every specimen showed semi-limbate, curved sutures and rounded periphery. No trace of raised sutures or longitudinal costae occurs. In fact, Jones's original form is a smooth marginulinid and the present species is distinct and must be correctly designated. Its chief characteristic is the extraordinary variability, and in regard to this, Sherborn & Chapman (1886) mentioned nine or ten different ornamentations among 100 individuals, all showing complete intergradation.

The similar species *Marginulina asperuliformis* Nuttall (1930) differs from the present one only in being less compressed and in lacking longitudinal ornamentation.

Marginulina elenae Tutkovski (1888) has much in common with *M. enbornensis*, but the last few chambers are smooth and separated by semi-limbate sutures. Holotype: (P. 41095(1)). Type level: Enborne Bore 31: depth 17.5 ft. Three other specimens (P. 41095(2–4)).

Marginulina glabra d'Orbigny

1826. *Marginulina glabra* d'Orbigny, *Ann. Sci. Nat.*, 7, 259.
1951. *Marginulina glabra* d'Orbigny: Marks, *Contr. Cush. Found. For. Res.*, **2,** 43.

One specimen (P. 41096).

Genus: **NODOSARIA** Lamarck, 1812

Nodosaria acuminata Hantken

1875. *Nodosaria acuminata* Hantken, *K. Ungar. Geol. Anst., Mitt. Jahrb.*, **4,** 28, pl. 2, fig 9; pl. 13, fig. 5.

One specimen (P. 41097).

Nodosaria adolphina (d'Orbigny)

1846. *Dentalina adolphina* d'Orbigny, *For. Foss. Bass. Tert. Vienne*, 51, pl. 2, figs. 18–20.
1886. *Dentalina adolphina* d'Orbigny: Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6**, 750, pl. 15, fig. 11.
1919. *Nodosaria adolphina* (d'Orbigny): Halkyard, *Manch. Mem.*, **62**, 79.

Remarks. The present specimens belong to the tuberculate form of the species. Two specimens (P. 41098(1–2)).

Nodosaria arundinacea (Costa)

1855. *Dentalina arundinacea* Costa, *Mem. Acad. Sci. Naples*, **2**, 17, pl. 1, fig. 26.

Two specimens (P. 41099(1–2)).

Nodosaria bacillum (Defrance)

1825. *Nodosaria baguette* Defrance, *Dict. Sci. Nat.*, **35**, 127, tab. 13, fig. 4.
1886. *Nodosaria bacillum* (Defrance): Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6**, 748, pl. 14, fig. 34.

One specimen (P. 41100).

Nodosaria consobrina (d'Orbigny)

Fig. B, 5, 6

1846. *Dentalina consobrina* d'Orbigny, *For. Foss. Bass. Tert. Vienne*, 46, pl. 2, figs. 1–3.
1865. *Dentalina consobrina* d'Orbigny var. *emaciata* Reuss, *Denkschr. d. K. Ak. Wiss. Wien*, **25**, 132, pl. 2, figs. 12, 13.
1870. *Nodosaria consobrina* (d'Orbigny): Reuss, *Sitzb. K. Ak. Wiss. Wien*, **62**, 473, pl. 9, figs. 1, 2, 8, 22; pl. 10, figs. 25–27.
1913. *Nodosaria consobrina* (d'Orbigny) var. *emaciata* Reuss: Cushman, *Bull. U.S. Nat. Mus. No.* 71, 56, pl. 27, fig. 9.
1927. *Nodosaria* (*Dentalina*) *consobrina* (d'Orbigny): Cushman & Hanna, *Proc. Calif. Acad. Sci.*, (4), **16**, 214.
1927. *Nodosaria consobriana emaciata* (Reuss): Hanna & Church, *Journ. Paleont.*, **1**, 199.

Remarks. d'Orbigny (1846) described this species as having an initial spine and simple, round aperture. Reuss (1865) stated that the variety *emaciata* has an initial spine and round aperture. Bagg (1912) stated that the species has an initial spine and fewer and less regular chambers than the variety; he must have altered his opinion, expressed in 1898, that the species has 'a neatly rounded proximal end'. Macfadyen (1930) referred to the variety as having an initial spine and added that the species lacks this feature. Similar differences in statements are found regarding the apertural characters. Reuss (1870) figured some specimens of the species with radiate apertures of which Marks (1951) stated that 'it seems doubtful that this latter was actually observed', adding that none of his specimens 'has been observed with a radiate aperture'. Marks altered the generic status of the species on the grounds that his specimens 'distinctly show the neck and lip typical of *Nodogenerina*'. If this is correct, it is probable that his specimens should not be assigned to the present species. Both d'Orbigny's holotype and the present specimens show a simple round aperture on the tapering end chamber and there is no apertural lip. It is impossible to determine the true generic position of Marks's specimens since he did not figure them. In the opinion of the author, the present species is correctly placed in the genus *Nodosaria*. Both rounded and radiate apertures have been observed and in neither case are they associated with any structure of lip-like appearance. The confusion existing in regard to the characters distinguishing the variety *emaciata* from the species has arisen because of the assumption that the two are actually distinct. Examination of numerous specimens with and without the initial spine shows that some which have no spine possess a small scar placed centrally on the sub-globular proloculum. It is probable that this represents the position of a former spine which has been broken in preservation. This is not unlikely in view of the fragile nature of the spine when present. The author is of the opinion that the species and its variety are, in fact, identical and, in this connection, it is interesting to note the statement by Heron-Allen & Earland (*in* Halkyard, 1919) that 'there seems little reason for perpetuating the varietal name in this very variable species. It is, moreover, singularly inappropriate, as the variety is almost always more strongly marked in its development and growth than the type.' Five specimens (P. 41101(1–5)).

Nodosaria latejugata Gümbel

1868. *Nodosaria latejugata* Gümbel, *K. Bayer Ak. Wiss. Munchen, Math.–Physik. Cl.*, **10**, 619, pl. 1, fig. 32.
1886. *Nodosaria badenensis* d'Orbigny: Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6**, 748, pl. 14, fig. 35.

One specimen (P. 41102).

Nodosaria longiscata d'Orbigny

Fig. B, 7, 8

1846. *Nodosaria longiscata* d'Orbigny, *For. Foss. Bass. Tert. Vienne*, 32, pl. 1, figs. 10–12.
1889. *Nodosaria longiscata* d'Orbigny: Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, 486, pl. 11, figs. 17, 18.

Remarks. Marks (1951) stated that the apertural region in his specimens of the present species is not clear, but on the evidence of the type figure, he suggested that the species may 'in reality belong to the genus *Nodogenerina*'. d'Orbigny's figure shows that the species has a simple, round aperture, but there is no apertural lip. In view of the absence of a lip in the holotype and the present specimens, the author considers it unjustifiable to alter the generic position of this species. Four specimens (P. 41103(1–4)).

Nodosaria natchitochensis (Howe)

1939. *Dentalina natchitochensis* Howe, *Louisiana Dept. Conserv., Geol. Surv., Bull. No.* 14, 45, pl. 6, fig. 6.

Remarks. The present specimen is identical with the holotype in almost all respects, even in size (both are 0.4 mm. long), but the latter is slightly curvilinear and the London Clay form is rectilinear. One specimen (P. 41104).

Nodosaria obliqua (Linné) var. **torsa** Koch

1923. *Nodosaria obliqua* (Linné) var. *torsa* Koch, *Eclog. Geol. Helv.*, **18,** 348, tf. 4.

One specimen (P. 41105).

Nodosaria obliquestriata (Reuss)

1851. *Dentalina obliquestriata* Reuss, *Zeitschr. d. deutsch. Geol. Ges.*, **3,** 63, pl. 3, figs. 11, 12.
1886. *Dentalina obliquestriata* Reuss: Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6,** 751, pl. 15, fig. 15.

One specimen (P. 41106).

Nodosaria ovulata Sherborn & Chapman

1886. *Nodosaria ovulata* Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6,** 747, pl. 14, fig. 27.

Remarks. The characters of both the initial and apertural ends are indeterminate as a result of the fact that the specimens deposited at the British Museum (Natural History) (P. 3708) by Sherborn & Chapman show neither end. This is also the case with the present specimen. One specimen (P. 41107).

Nodosaria pariana Hedberg

1937. *Nodosaria pariana* Hedberg, *Journ. Paleont.*, **11,** 672, pl. 91, fig. 5.

Two specimens (P. 41108(1–2)).

Nodosaria raphanistrum (Linné)

1767. *Nautilus raphanistrum* Linné, *Syst. Nat.*, 1163.
1886. *Nodosaria raphanistrum* (Linné): Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6,** 749, pl. 14, fig. 37.

One specimen (P. 41109).

Nodosaria soluta (Reuss)

1851. *Dentalina soluta* Reuss, *Zeitschr. d. deutsch. Geol. Ges.*, **3,** 60, pl. 3, fig. 4.
1886. *Nodosaria soluta* (Reuss): Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6,** 746, pl. 14, figs. 25, 26.

Remarks. *Nodosaria grandis* (Reuss, 1866) closely resembles the present species, but has less globose chambers. One specimen (P. 41110).

Nodosaria sp.

Description and remarks. The single specimen available has two chambers separated by an indistinct suture placed at right-angles to the longitudinal axis. Both chambers are slightly inflated and there is a well-marked constriction. There is an ornament of longitudinal costae which are continuous across the suture and run in a direction which is slightly oblique to the axis. Neither the initial nor the apertural end is present in this specimen. *Nodosaria helicata* Coryell & Rivero (1940) resembles it, but differs in possessing slightly more oblique costae which increase in number by intercalation and bifurcation. One specimen (P. 41111).

Nodosaria spinescens (Reuss)

1851. *Dentalina spinescens* Reuss, *Zeitschr. d. deutsch. Geol. Ges.*, **3**, 62, pl. 3, fig. 10.
1936. *Dentalina spinescens* Reuss: Palmer & Bermudez, *Mem. Soc. Cubana Hist. Nat.*, **10**, 262, pl. 15, fig. 12.

Remarks. There is nothing to add to the description given by Palmer & Bermudez (1936). Three specimens (P. 41112(1–3)).

Nodosaria spinulosa (Montagu)

1808. *Nautilus spinulosus* Montagu, *Test. Brit. Suppl.*, 86, pl. 19, fig. 5.
1886. *Dentalina spinulosa* (Montagu): Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6**, 750, pl. 15, fig. 13.
1949. *Nodosaria spinulosa* (Montagu): Bermudez, *Cush. Lab. For. Res.*, *Sp. Pub. No.* 25, 148, pl. 9, fig. 48.

Two specimens (P. 41113(1–2)).

Nodosaria subcanaliculata (Neugeboren) var. spinescens nov.

Fig. B, 9

Diagnosis. The test is long, rectilinear or slightly curvilinear with numerous chambers which are initially broader than they are high, later becoming inflated, higher than they are broad and with constrictions between them. The chambers are separated by indistinct sutures arranged at right-angles to the longitudinal axis. The first few chambers are ornamented by faint, slightly oblique, longitudinal costae, but these soon disappear and are replaced by an initial series of spines on the later chambers. The proloculum has a prominent, centrally placed initial spine. The end chamber has a stout terminal neck with the simple aperture at its end.

Remarks. The characters which distinguish this variety from the species are: the initial spine, the development of spines at the initial ends of the later chambers and the lesser number of chambers (usually about eleven as compared with between thirteen and fifteen in the species). Holotype: P. 41114. Type level: Upper London Clay, Whitecliff Bay, Isle of Wight (Sample 8).

Nodosaria vertebralis (Batsch)

1791. *Nautilus* (*Orthoceras*) *vertebralis* Batsch, *Conch. des Seesandees*, **3**, No. 6, pl. 2, fig. 6.

1886. *Dentalina vertebralis* (Batsch): Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6**, 752, pl. 14, fig. 39.
1949. *Nodosaria vertebralis* (Batsch): Bermudez, *Cush. Lab. For. Res.*, *Sp. Pub. No.* 25, 149, pl. 9, fig. 54.

Remarks. There is nothing to add to previous descriptions. One specimen (P. 41115).

Genus: PLANULARIA Defrance, 1824

Planularia sp.

Description and remarks. The test is compressed with the early chambers planispirally coiled and the later chambers separated by oblique, flush sutures and extending back towards the proloculum. The wall is smooth. The apertural region is damaged in the only specimen available, but there is an apertural neck at the outer margin of the end chamber. This species resembles *Lenticulina hartingi* ten Dam (1944) but has an apertural neck and is more compressed in apertural view. One specimen (P. 41116).

Genus: PSEUDOGLANDULINA Cushman, 1929

Cushman stated that this genus has a radiate aperture, but circular apertures can occur and have been previously recorded by Terquem (1863), Macfadyen (1941), and Barnard (1950). The type species of the genus *Glandulina*, *G. laevigata* d'Orbigny (1826), should be placed in the present genus in the author's opinion. Examination of numerous specimens has failed to produce one with an initial biserial end.

Pseudoglandulina laevigata (d'Orbigny)

1826. *Nodosaria* (*Glandulina*) *laevigata* d'Orbigny, *Ann. Sci. Nat.*, **7**, 252, pl. 10, figs. 1–3.
1951. *Pseudoglandulina laevigata* (d'Orbigny): Cushman & Stainforth, *Journ. Paleont.*, **25**, 147, pl. 26, fig. 6.

Description and remarks. The test is ovate with circular transverse section and pointed initial end. There are three to five chambers arranged uniserially and the end chamber occupies about two-thirds of the length of the test. The chambers are separated by distinct, straight, parallel, slightly depressed sutures and the wall is smooth. The radiate aperture is central and terminal on the end chamber. The similar species *Pseudoglandulina cubensis* Cushman & Bermudez (1937) can be distinguished by its large apertural neck and radiate costae round the aperture. Two specimens (P. 41117(1–2)).

Pseudoglandulina nucula (Neugeboren)

1850. *Glandulina nucula* Neugeboren, *Ver. Naturw, Hermannstadt, Ungarn, Jahrg.*, 1, 51, pl. 1, fig. 6.

One specimen (P. 41118).

Pseudoglandulina obtusissima (Reuss)

1863. *Glandulina obtusissima* Reuss, *Sitzb. K. Ak. Wiss. Wien, Math.-Naturw. Cl.*, **48,** 66, pl. 8, figs. 92, 93.
1886. *Glandulina obtusissima* Reuss: Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6,** 746, pl. 14, fig. 21.

Remarks. Examination of the specimen figured by Sherborn & Chapman (1886) showed that their figure is inaccurate. The two chambers visible externally are of equal size, not unequal as drawn. In this respect, the specimen differs from the present ones which, while also two-chambered, have the end chamber larger than the initial one. Two specimens (P. 41119(1–2)).

Pseudoglandulina ovata (Cushman & Applin)

1926. *Nodosaria* (*Glandulina*) *laevigata* d'Orbigny var. *ovata* Cushman & Applin, *Bull. Amer. Assoc. Petrol. Geol.*, **10,** 169, pl. 7, figs. 12, 13.
1949. *Pseudoglandulina ovata* (Cushman & Applin): Bermudez, *Cush. Lab. For. Res., Sp. Pub. No.* 25, 162, pl. 10, fig. 39.

Remarks. There is nothing to add to previous descriptions. On specimen (P. 41120).

Pseudoglandulina tumida sp. nov.

Fig. B, 10

Diagnosis. The test is between one-and-a-half and twice as long as it is broad, with the maximum breadth attained by the penultimate chamber. It tapers towards the rounded initial end and the early chambers are broader than they are high. The end chamber is conical in shape with the aperture at the point. The preceding chambers are separated by indistinct sutures arranged at right-angles to the longitudinal axis. The wall is granular throughout, except for the end chamber where it is smooth and hyaline. The aperture is simple, terminal and central. Holotype: P. 41121. Type level: Enborne Bore 31: depth 17.5 ft.

Genus: **SARACENARIA** Defrance, 1824

Saracenaria italica Defrance var. **spinulosa** Sherborn & Chapman

1886. *Cristellaria italica* (Defrance) var. *spinulosa* Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6,** 754, pl. 15, figs. 24, 25.

Remarks. The variety differs from the species in having a spinose ornament. One specimen (P. 41122).

Genus: **TRISTIX** Macfadyen, 1941

Tristix sp.

Description. The fragmentary specimens available are insufficient to enable an accurate specific determination to be made. They comprise end chambers of triangular cross-section and hemispherical shape, the sides of the triangle being convex outwards. The simple aperture is central on the upper and hemi-spherical part of the test, and three ridges occur on this surface joining the apertural region with the three angles of the triangle.

Remarks. Sherborn & Chapman (1886) figured a similar specimen with an additional (penultimate) chamber under the name *Rhabdogonium tricarinatum* (d'Orbigny, 1826). Examination of this specimen (P. 3659) at the British Museum (Natural History), shows that it does not belong to d'Orbigny's species which has no ridges on the apertural surface, which is flat with eccentric aperture. The resemblance to the present form is close, but it has a radiate aperture. According to Glaessner (1945), *Tristix* may possess either a simple or radiate aperture, so the two forms may belong to the same species and this may constitute a new species, but the present author considers the available specimens too imperfect to justify the erection of the latter. One specimen (P. 41123).

Family: LITUOLIDAE

Subfamily: HAPLOPHRAGMIINAE

Genus: **HAPLOPHRAGMOIDES** Cushman, 1910

Haplophragmoides discus (Rzehak)

1886. *Haplophragmium discus* Rzehak, *Naturf. Ver. Brunn, Verh., Brno*, **24,** 78, pl. 1, fig. 1.

Two specimens (P. 41124(1–2)).

Family: MILIOLIDAE

Genus: **QUINQUELOCULINA** d'Orbigny, 1826

Quinqueloculina akneriana d'Orbigny

Fig. B, 11, 12

1846. *Quinqueloculina akneriana* d'Orbigny, *For. Foss. Bass. Tert. Vienne*, 290, pl. 18, figs. 16–21.

1855. *Quinqueloculina ermani* Bornemann, *Zeitschr. d. deutsch. Geol. Ges.*, **7,** 353.

1886. *Miliolina seminulum* (Linné): Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6,** 742, pl. 14, fig. 1.

1924. *Quinqueloculina goodspeedi* Hanna & Hanna, *Washington Publ. Geol.*, **1,** 58.

1951. *Quinqueloculina akneriana* d'Orbigny: Marks, *Contr. Cush. Found. For. Res.*, **2,** 38.

Remarks. Marks (1951) stated that this species has been described under many different names and 'most of the modern authors have made it a synonym of *Q. seminula* (Linné), but as Thalmann has pointed out, Linnaeus never published an adequate figure for the recognition of the species'. One specimen (P. 41125).

Quinqueloculina arctica Cushman

1886. *Miliolina ferrussacii* (d'Orbigny): Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6**, 742, pl. 14, fig. 5.
1933. *Quinqueloculina arctica* Cushman, *Smithson. Inst., Misc. Coll.*, **89**, No. 9, 2, pl. 1, fig. 3.

Remarks. Some authors have confused this species with *Quinqueloculina ferrussacii* d'Orbigny (1826), but the latter is more elongate with a prominent neck. Two specimens (P. 41126(1–2)).

Quinqueloculina imperialis Hanna & Hanna, var. **porterensis** Rau

1948. *Quinqueloculina imperialis* Hanna & Hanna var. *porterensis* Rau, *Journ. Paleont.*, **22**, 159, pl. 27, figs. 9–11.

Two specimens (P. 41127(1–2)).

Quinqueloculina ludwigi Reuss

1866. *Quinqueloculina ludwigi* Reuss, *Sitzb. K. Ak. Wiss. Wien, Math.-Nat. Cl., Denkschr.*, **25**, 126, pl. 1, fig. 12.
1867. *Quinqueloculina gracilis* Karrer, *Sitzb. K. Ak. Wiss. Wien*, **55**, Art. 1, 361.

Two specimens (P. 41128(1–2)).

Quinqueloculina sp.

Description. The test is almost circular in plan view being only slightly longer than it is broad and the chambers are separated by curved, depressed sutures. The apertural view is sub-triangular in shape with the round, toothless aperture flush with the surface of the test. One specimen (P. 41129).

Genus: **TRILOCULINA** d'Orbigny, 1826

Triloculina pulchella d'Orbigny

1846. *Triloculina pulchella* d'Orbigny, *For. Foss. Bass. Tert. Vienne*, 279, pl. 17, figs. 19–21.

One specimen (P. 41130).

Family: NONIONIDAE

Genus: **ELPHIDIUM** Montfort, 1808

Elphidium concinnum Nicol

1944. *Elphidium concinnum* Nicol, *Journ. Paleont.*, **18**, 179, pl. 29, figs. 5, 9.

Remarks. *Elphidium fax* subsp. *barbarense* Nicol (1944) resembles the present species, but has more numerous retral processes and these tend to become absorbed in the later stages of growth. One specimen (P. 41131).

Genus: **NONION** Montfort, 1808

Nonion applini Howe & Wallace

Fig. C, 1–3

1932. *Nonion applini* Howe & Wallace, *Louisiana Dept. Conserv., Geol. Surv. Bull. No.* 2, 51, pl. 9, fig. 4.

Remarks. It is probable that several specimens identified as *Nonion scaphum* (Fichtel & Moll, 1803) in the literature should be assigned to the present species. The latter differs from *N. scaphum* in having granular umbilical regions, less compressed test, closer coiled form and completely involute condition. Two specimens (P. 41132(1–2)).

Nonion elongatum (d'Orbigny)

1826. *Nonionina elongata* d'Orbigny, *Ann. Sci. Nat.*, **7**, 128.
1904. *Nonionina elongatum* d'Orbigny: Fornasini, *Mem. Roy. Accad. Sci. Inst. Bologna*, (6), **1**, pl. 3, fig. 4.

Three specimens (P. 41133(1–3)).

Nonion scaphum (Fichtel & Moll)

1798. *Nautilus scapha* Fichtel & Moll, *Test. Micr.*, 105, pl. 19, figs. d–f.
1951. *Nonion scaphum* (Fichtel & Moll) : Marks, *Contr. Cush. Found. For. Res.*, **2**, 49, pl. 5, fig. 16.

Three specimens (P. 41134(1–3)).

Nonion umbilicatulus (Montagu)

Fig. C, 4–6

1803. *Nautilus umbilicatulus* Montagu, *Test. Brit.*, 191.
1884. *Nonionina umbilicatula* (Montagu): Brady, '*Challenger*' *Rep.*, **9** (Zool.), 726, pl. 109, figs. 8, 9.
1927. *Nonion umbilicatulus* (Montagu): Cushman, *Journ. Paleont.*, **1**, 156, pl. 25, figs. 12, 13.

Three specimens (P. 41135(1–3)).

Genus: **NONIONELLA** Cushman, 1926

Nonionella auris (d'Orbigny)

Fig. C, 7–9

1839. *Valvulina auris* d'Orbigny, *For. Amer. Merid.*, 47, pl. 2, figs. 15–17.
1925. *Nonionina auris* (d'Orbigny): Cushman, *Contr. Cush. Lab. For. Res.*, **1**, 44, pl. 7, fig. 3.
1926. *Nonionella miocenica* Cushman, *Contr. Cush. Lab. For. Res.*, **2**, 64.
1927. *Nonionella auris* (d'Orbigny): Cushman, *Contr. Cush. Lab. For. Res.*, **3**, pl. 10, fig. 3.

Remarks. In the type description of *Nonionella miocenica* Cushman (1926) distinguished it from the present species only by its fewer chambers, stating that it possesses from eight to ten in the last whorl. The present author considers the two species as identical because *N. auris* may have from eight to eleven chambers in this whorl and the type figure shows ten chambers in it. Two specimens (P. 41136(1–2)).

Nonionella jacksonensis Cushman

1933. *Nonionella jacksonensis* Cushman, *Contr. Cush. Lab. For. Res.*, **9**, 10, pl. 1, fig. 23.

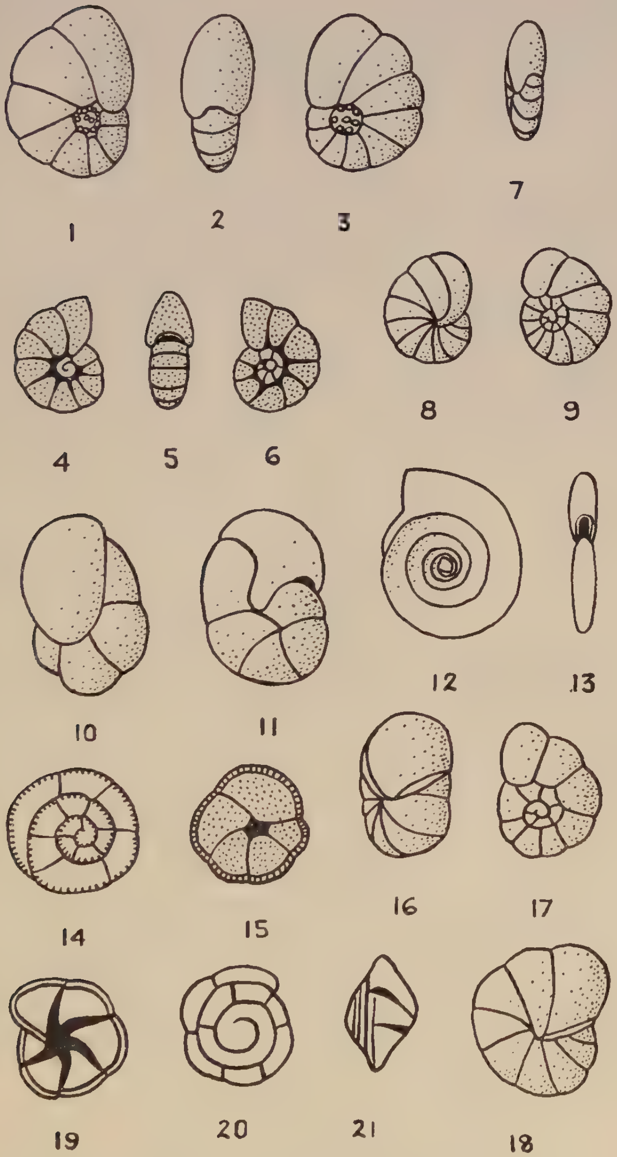


Fig. C. London Clay Foraminifera

Remarks. This species is closely similar to *Nonionella turgida* (Williamson, 1858), but as Cushman (1933) pointed out, the general shape is slightly different and 'the chambers of our species are broader and usually fewer'. There are from eight to ten chambers in the last whorl of the present species. Two specimens (P. 41137(1–2)).

Nonionella sp.

Fig. C, 10, 11

Description and remarks. The test is broad and asymmetrical in apertural view, involute ventrally with five chambers in the last whorl separated by slightly curved, depressed sutures. The end chamber is inflated with an umbilical extension. The dorsal side of the test is slightly evolute and the last chamber has a curious inward extension. The periphery is rounded and lobulate and the wall is smooth. The aperture is low, arched and situated at the base of the apertural face of the end chamber near the periphery and on the dorsal side. The dorsal extension of the end chamber and the anomalous position of the aperture incline the author to the view that this form is abnormal. One specimen (P. 41138).

Family: OPHTHALMIDIIDAE

Subfamily: CORNUSPIRINAE

Genus: **CORNUSPIRA** Schultze, 1854

Cornuspira involvens (Reuss)

1850. *Operculina involvens* Reuss, *Sitzb. K. Ak. Wiss. Wien, Math.–Nat. Cl., Denkschr.*, **1**, 370, pl. 46, fig. 20.

1889. *Cornuspira involvens* (Reuss): Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, 484, pl. 11, figs. 4, 5.

Remarks. *Cornuspira tasmanica* Parr (1950) resembles the present species, but is larger and less regularly coiled. Three specimens. (P. 41139(1–3)).

Cornuspira lewisensis Beck

Fig. C, 12, 13

1943. *Cornuspira lewisensis* Beck, *Journ. Paleont.*, **17**, 594, pl. 101, figs. 4, 5.

Description. The test is compressed, planispirally coiled, non-septate, depressed umbilically and evolute, showing several whorls of which the last is the most prominent, occupying nearly half the radius at the apertural end. The wall is smooth and imperforate and the aperture is formed by the open end of the last whorl. Two specimens (P. 41140(1–2)).

Family: POLYMORPHINIDAE

Subfamily: POLYMORPHININAE

Genus: **GLANDULINA** d'Orbigny, 1826

Glandulina conica Neugeboren

1850. *Glandulina conica* Neugeboren, *Ver. Mitth. Siebenbürg Ver. Nat.*, **1,** 51, pl. 1, fig. 5.
1949. *Pseudoglandulina conica* (Neugeboren): Bermudez, *Cush. Lab. For. Res., Sp. Pub. No.* 25, 161, pl. 10, fig. 38.

Remarks. This species has been replaced in the original genus on the basis of specimens which show the initially biserial end. One specimen (P. 41141).

Genus: **GLOBULINA** d'Orbigny, 1839

Globulina gibba d'Orbigny

1826. *Polymorphina (Globulina) gibba* d'Orbigny, *Ann. Sci. Nat.*, **7,** 266.
1886. *Polymorphina gibba* d'Orbigny: Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6,** 755, pl. 16, fig. 5.
1949. *Globulina gibba* d'Orbigny: Bermudez, *Cush. Lab. For. Res., Sp. Pub. No.* 25, 164, pl. 11, figs. 6, 7.

Remarks. Brady (1884) stated that *G. gibba* grades imperceptibly into *Globulina lactea* (Walker & Jacob, 1798), but although both species occur in the London Clay, no intermediate forms have been found. The author regards the two species as distinct. Two specimens (P. 41142(1–2)).

Globulina lactea (Walker & Jacob)

1798. *Serpula lactea* Walker & Jacob, *Adams's Essays, Kanmacher Ed.*, 634, pl. 14, fig. 4.
1927. *Polymorphina lactea* (Walker & Jacob): Franke, *Danmarks Geol. Undersøgelse* 11, Rke. Nr. 46, 34, pl. 3, fig. 13.

Remarks. Brady (1884) stated that this species intergrades with *G. gibba* in the spheroidal direction and with *Pyrulina gutta* d'Orbigny (1826) in the elongate direction, but although all three species occur in the London Clay, this intergradation has not been observed. Two specimens (P. 41143(1–2)).

Genus: **PYRULINA** d'Orbigny, 1839

Pyrulina gutta d'Orbigny

1826. *Polymorphina (Pyrulina) gutta* d'Orbigny, *Ann. Sci. Nat.*, **7,** 267, pl. 12, figs. 5, 6.

One specimen (P. 41144).

Family: ROTALIIDAE

Subfamily: BAGGININAE

Genus: **BAGGINA** Cushman, 1926

Baggina bradyi (Brotzen)

1884. *Discorbina allomorphinoides* (Reuss): Brady, '*Challenger*' *Rep.*, **9** (Zool.), 654, pl. 91, figs. 5, 8.

1936. *Valvulineria bradyi* Brotzen, *Sver. Geol. Unders. Avh.*, Ser. C, No. 395, (Arsb. 30, No. 3), 154.

One specimen (P. 41145).

Subfamily: DISCORBINAE

Genus: DISCORBIS Lamarck, 1804

Discorbis chapmani sp. nov.

Fig. C, 14, 15

1886. *Discorbina rosacea* (d'Orbigny): Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6**, 756, pl. 16, fig. 11.

Diagnosis. The test is trochoid and unequally biconvex, evolute on the dorsal side, a low conical surface with several whorls visible and involute on the slightly convex ventral side. The periphery is lobulate and the edge of the test is milled on both sides. There are from four to six chambers in the last whorl separated by curved, slightly limbate sutures. The aperture is large, central and umbilical in position on the ventral side.

Remarks. Sherborn & Chapman (1886) assigned their specimens (P. 3647) incorrectly. Cushman (1931) stated that 'of the many records' of *D. rosacea*, 'few . . . figure the species and practically none of these can be referred to the same species'. No type description or figure is available, but d'Orbigny's model is quite unlike the present specimens and those of Sherborn & Chapman. Holotype: P. 41146. Type level: Enborne Bore 38: depth 120 ft.

Genus: GYROIDINA d'Orbigny, 1826

Gyroidina soldanii d'Orbigny

1826. *Gyroidina soldanii* d'Orbigny, *Ann. Sci. Nat.*, **7**, 278.

1949. *Gyroidina soldanii* d'Orbigny: Bermudez, *Cush. Lab. For. Res.*, *Sp. Pub. No.* 25, 254, pl. 17, figs. 52–4.

Remarks. *Gyroidina basicrassata* Bermudez (1949) closely resembles this species, but has the bases of the end chambers on the ventral side strongly thickened. Two specimens (P. 41147(1–2)).

Gyroidina sp.

Description. The test is trochospiral with slightly convex dorsal surface and conical ventral surface. The ventral side is involute, but the number of chambers comprising the last whorl is obscure, though numerous. The sutures are curved and appear to be slightly limbate. The evolute dorsal side shows a central boss and an indistinct, depressed spiral suture. The apertural region is broken in the single specimen available.

Remarks. This species is similar to *Gyroidina orbicularis* d'Orbigny (1826), but the preservation is not sufficiently good to enable the identification to be made accurately. One specimen (P. 41148).

Genus: **VALVULINERIA** Cushman, 1926

Valvulineria barnardi sp. nov.

Fig. C, 16–18

Diagnosis: The test is trochospiral, evolute dorsally showing an inner whorl, involute ventrally with usually nine chambers in the last whorl. The chambers are inflated and separated by curved, slightly depressed sutures; the periphery is lobulate. The wall is smooth and the aperture extends from the umbilical region on the ventral side to the periphery and is partly covered by a lip-like extension of the chamber wall. Holotype: P. 41149. Type level: Enborne Bore 34: depth 35.5 ft.

Valvulineria byramensis (Cushman & Todd)

1946. *Gyroidina byramensis* Cushman & Todd, *Contr. Cush. Lab. For. Res.*, **22,** 98, pl. 16, figs. 19–21.

Remarks. This species possesses a strongly biconvex test and a lip-like extension of the end chamber towards the umbilicus on the ventral side which partly covers the aperture—features not found in the typically low-spired genus *Gyroidina*. Hence the generic status has been altered. One specimen (P. 41150).

Subfamily: ROTALIINAE

Genus: **ALABAMINA** Toulmin, 1941

Alabamina scitula Bandy

1889. *Pulvinulina elegans* (d'Orbigny): Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, 487, pl. 11, figs. 30–2.
1949. *Alabamina scitula* Bandy, *Bull. Amer. Paleont.*, **32,** No. 131, 89, pl. 14, fig. 6.

Remarks. *Alabamina obtusa* (Burrows & Holland, 1897) is similar to this species, but the later chambers show a relatively greater height and the periphery is more acute. Two specimens (P. 41151(1–2)).

Genus: **EPONIDES** Montfort, 1808

Eponides punctulata (d'Orbigny)

1826. *Rotalia punctulata* d'Orbigny, *Ann. Sci. Nat.*, **7,** 273.
1886. *Pulvinulina punctulata* (d'Orbigny) var. Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6,** 758, pl. 16, fig. 22.

One specimen (P. 41152).

Eponides umbonata (Reuss)

Fig. C, 19–21

1851. *Rotalina umbonata* Reuss, *Zeitschr. d. deutsch. Geol. Ges.*, **3,** 75, pl. 5, fig. 35.
1884. *Truncatulina tenera* Brady, '*Challenger*', *Rep.*, **9** (Zool.), 665, pl. 95, fig. 11.
1946. *Eponides umbonata* (Reuss): Colom, *Bull. Inst. Geol. Lucas Mallada No.* 3, 63, pl. 4, figs. 117, 118.

Three specimens (P. 41153(1–3)).

Genus: **ROTALIA** Lamarck, 1804

Rotalia beccarii (Linné)

1767. *Nautilus beccarii* Linné, *Syst. Nat.*, Ed. 12, 1162.
1945. *Rotalia beccarii* (Linné): Cushman, *Cush. Lab. For. Res., Sp. Pub. No.* 13, 21, pl. 5, fig. 9.

One specimen (P. 41154).

Family: TEXTULARIIDAE

Subfamily: SPIROPLECTAMMININAE

Genus: **BOLIVINOPSIS** Yakovlev, 1891

Bolivinopsis carinata (d'Orbigny)

1826. *Textularia carinata* d'Orbigny, *Ann. Sci. Nat.*, **7,** 263.
1919. *Bigenerina capreolus* (d'Orbigny): Halkyard, *Manch. Mem.*, **62,** 35, pl. 2, figs. 10–13.
1951. *Spiroplectammina carinata* (d'Orbigny): Marks, *Contr. Cush. Found. For. Res.*, **2,** 35, pl. 6, fig. 2.

Two specimens (P. 41155(1–2)).

Bolivinopsis expansa (Plummer)

Fig. D, 1

1926. *Textularia carinata* d'Orbigny var. *expansa* Plummer, *Bull. Univ. Texas No.* 2644, 67, pl. 3, fig. 3.

Remarks. In 1948, Cushman raised Plummer's variety to specific rank and named it *Spiroplectammina plummerae*, noting that the name *Spiroplectammina expansa* had been used for a different species in 1941 by Le Roy. Plummer used the name in 1926 and this precedes Le Roy's, hence *Spiroplectammina expansa* (Plummer) has priority and Le Roy's name is invalid. *S. plummerae* is, of course, redundant. The author has altered the generic name for reasons previously stated. Two specimens (P. 41156(1–2)).

Subfamily: TEXTULARIINAE

Genus: **TEXTULARIA** Defrance, 1824

Textularia broussardi Howe & Wallace

1932. *Textularia broussardi* Howe & Wallace, *Louisiana Dept. Conserv., Geol. Surv. Bull. No.* 18, pl. 1, fig. 3.

One specimen (P. 41157).

Textularia lontensis Lalicker

1935. *Textularia lontensis* Lalicker, *Contr. Cush. Lab. For. Res.*, **11,** 49, pl. 7, fig. 2.

One specimen (P. 41158).

Textularia oveyi sp. nov.

Fig. D, 2, 3

Diagnosis. The test is large, elongate and tapers slightly towards the initial end which is rounded. In apertural view, it is broad and lobulate. The chambers show a slight increase in size throughout, but the end pair are much larger than those which precede them and are markedly inflated. The chambers are separated by slightly depressed sutures which are almost or quite horizontal. They are indistinct at the initial end. The wall is smoothly arenaceous and the oval, lipped aperture is placed at the base of the apertural face of the end chamber.

Remarks. *Textularia thanetana* Lalicker (1935) from the Thanet Sands of Pegwell Bay, resembles this species, but can be distinguished by its oblique sutures (making an angle of twenty-five to thirty degrees with the horizontal), wider and lower aperture and more rhomboid-shaped transverse section. Holotype: P. 41159. Type level: Enborne Bore 38: depth 120 ft.

Textularia porrecta Brady

1884. *Textularia agglutinans* d'Orbigny var. *porrecta* Brady, '*Challenger*' *Rep.*, **9** (Zool.), 364, pl. 43, fig. 4.

One specimen (P. 41160).

Textularia secasensis Lalicker & McCulloch

1940. *Textularia secasensis* Lalicker & McCulloch, *S. Calif., Univ. Pub. Allan Hancock Pacific Exped.*, **6,** 141, pl. 16, fig. 24.

One specimen (P. 41161).

Family: VALVULINIDAE

Subfamily: VALVULININAE

Genus: **CLAVULINA** d'Orbigny, 1826

Clavulina parisiensis d'Orbigny

1826. *Clavulina parisiensis* d'Orbigny, *Ann. Sci. Nat.*, **7,** p. 268.
1937. *Clavulina parisiensis* d'Orbigny: Ovey, *Journ. Roy. Micr. Soc.*, **57,** 116, fig. 6.

Three specimens (P. 41162(1–3)).

Family: VERNEUILINIDAE

Genus: **GAUDRYINA** d'Orbigny, 1839

Subgenus: GAUDRYINA Cushman, 1940

Gaudryina (Gaudryina) ashfordi sp. nov.

Fig. D, 4, 5

1886. *Gaudryina pupoides* d'Orbigny: Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6,** 743, pl. 14, fig. 7.

Diagnosis. The test is initially triserial with triangular transverse section, later becoming biserial with oval transverse section. The triserial part of the test tapers rapidly and comprises only about one-fifth of the length in

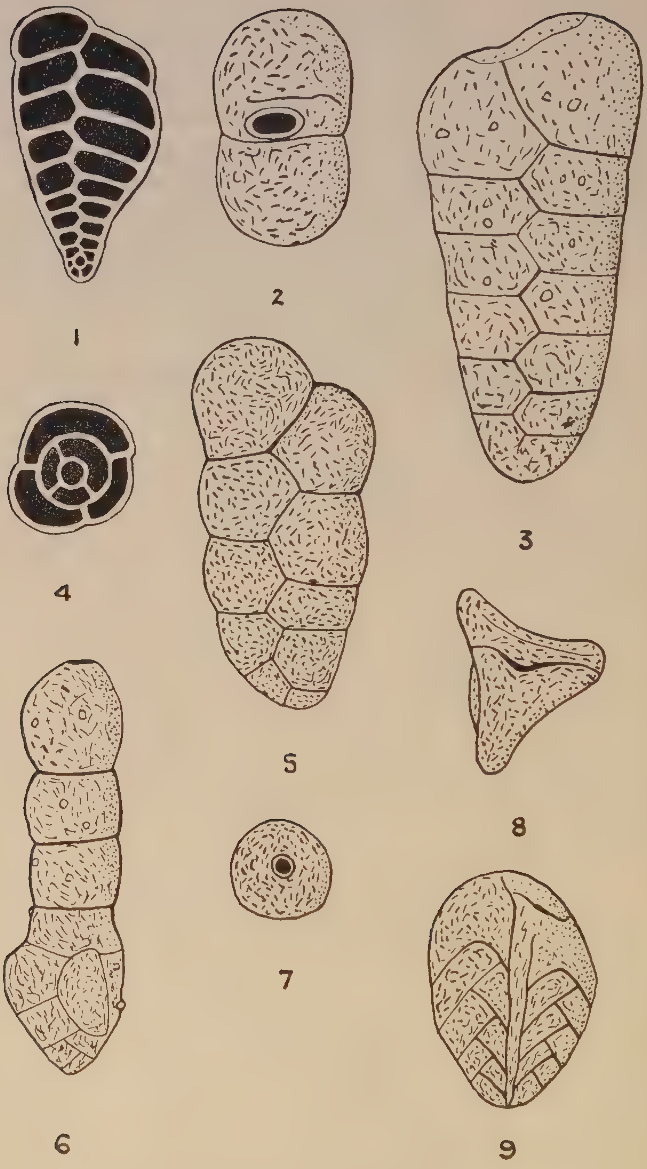


Fig. D. London Clay Foraminifera

fully-grown specimens; it has flat sides. In the biserial part, the test is parallel-sided with lobulate periphery and few, inflated chambers separated by slightly depressed sutures arranged at right-angles to the longitudinal axis. The wall is coarsely arenaceous and there is a narrow, crescentic aperture at the base of the end chamber.

Remarks. Examination of the specimen figured by Sherborn & Chapman (1886) (P. 3664) showed that it is identical with this species. The similar form *Gaudryina stavensis* Bandy (1949) differs in having more chambers which are less inflated and lower, and in having a relatively larger triserial part. Holotype: P. 41163(1). Type level: Enborne Bore 31: depth 17.5 ft. Other specimen (P. 41163(2)).

Genus: **PSEUDOCLAVULINA** Cushman, 1936

Pseudoclavulina anglica Cushman

Fig. D, 6, 7

1886. *Clavulina communis* d'Orbigny: Sherborn & Chapman, *Journ. Roy. Micr. Soc.*, (2), **6**, 743, pl. 15, fig. 1.

1936. *Pseudoclavulina anglica* Cushman, *Cush. Lab. For. Res.*, *Sp. Pub. No.* 6, 18, pl. 3, fig. 5.

Remarks. The present species was recorded from Clapham at 100 ft. above the base of the London Clay by Cushman (1936). One specimen (P. 41164).

Genus: **VERNEUILINA** d'Orbigny, 1840

Verneuilina carinata Hermes

Fig. D, 8, 9

1945. *Verneuilina carinata* Hermes, *Utrecht Univ., Geogr. Geol. Meded., Physiogr.—geol. Rks.*, (2), No. 7, 32, pl. 4, figs. 1, 2.

One specimen (P. 41165).

7. PALAEOECOLOGY

Investigation of the Foraminifera of the London Clay showed that more than one-third of the total number of species recorded are members of the Lagenidae, and of the remainder, about four-fifths belong to nine families, namely, in order of size, the Anomalinidae, Rotaliidae, Buliminidae, Nonionidae, Textulariidae, Miliolidae and Chilostomellidae, Polymorphinidae and Globigerinidae.

Lithological and macrofaunal evidence, coupled with information derived from the floral remains, have revealed that these lived under shallow, warm (possibly sub-tropical), marine conditions. They are most abundant in the clay beds, becoming much less frequent in sandy or silty beds. The presence of the latter and the occurrence of pebble-beds and current-bedding indicate that occasionally the depth of the sea was shallow, while the crocodilian fragments, fossil wood, fruits and seeds, so common at Sheppey, suggest proximate estuarine conditions. The clay beds, which typify the formation, represent deeper water conditions. Altogether, much fluctuation in depth must have occurred. The majority of the Foraminifera were benthonic in their mode of life and show the usual structural adaptations of the test. The composition of the London Clay assemblages is very similar to that of assemblages recorded by Hedberg (1937) from the Miocene of Venezuela. These latter were characteristic of warm, shallow water conditions and include species of *Elphidium*, *Nonion*, *Textularia*, *Cibicides* and *Quinqueloculina*, associated with mottled and grey clays with lignite and iron carbonate. The resemblance illustrates the validity of Hedberg's assertion that 'facies is more important than geologic age in determining the composition of a Tertiary foraminiferal fauna'. Using the foraminiferal fauna, Jones & Sherborn came to the conclusion that the London Clay sea was about 100 fathoms deep, but the author believes this statement to be unjustifiable in view of the conflicting evidence regarding the bathymetric distribution of surviving species in present seas and the evidence for constant fluctuation referred to previously. In fact, the foraminiferal evidence is far too equivocal for use in accurate depth-determination and this is also true of temperature indication. As Glaessner (1945) stated, 'the temperature has no direct influence on the minor taxonomic features of the test' and 'structural similarity between a fossil and a Recent species does not necessarily indicate a similar temperature range of a fossil form'. Substantially the same point was made by Wrigley (1924) with reference to the Gastropoda of this formation. Thus, although there can be no doubt of the conditions of life of the Foraminifera, it should be emphasised that, in themselves, these animals are of little use as palaeoecological indicators.

8. STRATIGRAPHICAL DISTRIBUTION

The accompanying range chart indicates the distribution of the Foraminifera in the Enborne Valley Bore 38 (facing p. 174). The distribution of the Foraminifera obtained from the other seventeen bores drilled in the Enborne Valley and the four bores drilled in the vicinity of the British Museum (Natural History) is recorded on four range charts available for examination at the Museum. The distribution of the Foraminifera in the samples obtained from the four other localities is as follows:

a. Isle of Sheppey

From the seven samples examined, twenty species were obtained. All the samples were from the same horizon in the upper London Clay. The species were:

Anomalina globulosa
Bulimina ovata
Uvigerina pigmea
Globigerina bulloides
Globigerina dubia
Nodogenerina hirsuta
Dentalina bradyensis
Dentalina pauperata
Lenticulina articulata
Lenticulina inornata
Lenticulina umbonata
Marginulina enbornensis
Nonion elongatum
Nonion umbilicatulus
Cornuspira involvens
Globulina gibba
Discorbis chapmani
Bolivinopsis expansa
Clavulina parisiensis
Pseudoclavulina anglica

b. Oxshott, Surrey

From the five samples examined, five species were recorded. Sample 1 was taken from the base of the exposure.

The species were the following and the samples from which derived are indicated by the figures following them:

Bulimina ovata	1
Pullenia quinqueloba	1
Lenticulina articulata	1
Discorbis chapmani	1, 2, 3, 4, 5
Bolivinopsis expansa	2, 4, 5

c. Alum Bay, Isle of Wight

From the fifteen samples examined, fourteen species were recorded. Sample 1 was taken from the basal beds and the others were evenly spaced upwards through the succession.

The species were as follows (the numbers denote the samples from which they were obtained):

Cibicides lobatulus	5, 8, 10
Cibicides praecursorius	5, 8
Bolivina punctata	5
Pullenia quinqueloba	8, 10, 12
Lenticulina articulata	5
Lenticulina texanus	5, 8
Quinqueloculina imperialis var. *porterensis*	2, 5
Quinqueloculina ludwigi	5
Nonion applini	5, 8
Nonion umbilicatulus	5, 8
Alabamina scitula	5, 8
Bolivinopsis carinata	5, 8, 10
Bolivinopsis expansa	5, 8
Clavulina parisiensis	5

d. Whitecliff Bay, Isle of Wight

From the ten samples examined, twenty-three species were recorded. The ten were numbered 1 to 10, the first five being taken from the lowest fifty feet of the formation and the rest at regularly spaced intervals.

The species were as follows (the numbers denote the samples from which they were obtained):

Planulina anglica	7
Cibicides lobatulus	8
Cibicides pseudoungerianus	7
Uvigerina aculeata var. *asperula*	7
Bolivina advena	7
Bolivina punctata	7
Pullenia bulloides	7
Pullenia quinqueloba	7
Pullenia quinqueloba var. *quadriloba*	7
Pullenia salisburyi	7
Lagena striata	7
Dentalina bradyensis	7
Lenticulina articulata	8, 9
Lenticulina ellisori	7
Nodosaria subcanaliculata var. *spinescens*	8
Quinqueloculina imperialis var. *porterensis*	8
Triloculina pulchella	8
Nonion umbilicatulus	7
Elphidium concinnum	8
Discorbis chapmani	7
Rotalia beccarii	8
Bolivinopsis expansa	7
Clavulina parisiensis	7

9. STRATIGRAPHICAL SIGNIFICANCE

Examination of the recorded distributions of the Foraminifera in the samples studied show that, in general, they are confined to distinct facies and have little use as horizon markers in consequence. Mostly they occur only in the clay beds and are seldom present in large numbers of individuals. The relatively small number of species found, both in sandy and clayey deposits, is usually represented by numerous individuals and forms the basis of the assemblages at different horizons, the numbers being only slightly reduced in the sandy beds with no alteration in dimensions. This group of species is the first to appear and co-exists with the facies-forms during the period when the clay beds were being laid down (the lower Middle London Clay). Subsequently, they survive the latter into the recurrent sandy conditions of the upper Middle and Upper London Clay.

These facts make it evident that no zonal scheme can be advanced for the formation based on the Foraminifera.

ACKNOWLEDGMENTS

The author wishes to express his gratitude to Dr. T. Barnard for advice and encouragement on all aspects of the present work. To Professor H. L. Hawkins, the author is indebted for the supply of material from the bores drilled by the Metropolitan Water Board in 1948 and 1949 in connection with the Enborne Valley Reservoir project. Many thanks are due to Mr. C. D. Ovey for the supply of material from the bores drilled by the Ministry of Works in 1949 in the precincts of the British Museum (Natural History) and for access to the foraminiferal collections in the latter.

EXPLANATION OF FIGURES

FIGURE A

1, 2, 3. *Planulina anglica* sp. nov. Ventral, apertural and dorsal views of holotype. × 55. P. 41035.
4, 5, 6. *Cibicides lobatulus* (Walker & Jacob). Apertural, ventral, and dorsal views. × 55. P. 41038 (1).
7. *Bulimina ovata* d'Orbigny. Side view. × 55. P. 41043 (1).
8. *Pullenia quinqueloba* (Reuss). Side view. × 55. P. 41053 (1).
9. *Dentalina sherborni* sp. nov. Side view of holotype. × 55. P. 41077.
10, 11. *Lenticulina articulata* (Reuss). Side views of two specimens. × 38. P. 41078 (1, 2).
12. *Lenticulina ellisori* sp. nov. Side view of holotype. × 55. P. 41081.
13, 14. *Lenticulina flexuosa* Sherborn & Chapman. Side and apertural views. × 38. P. 41082.

FIGURE B

1, 2, 3, 4. *Marginulina enbornensis* sp. nov.
    1 = Side view of holotype. × 35. P. 41095 (1).
    2 = Side view of another specimen. × 35. P. 41095 (2).
    3 = Side view of a third specimen. × 35. P. 41095 (3).
    4 = Section of megalospheric specimen to show initial planispiral coiling. × 35. P. 41095 (4).
5, 6. *Nodosaria consobrina* (d'Orbigny). Side views of two specimens. × 50. P. 41101 (1, 2).
7, 8. *Nodosaria longiscata* d'Orbigny. Side views of two specimens showing initial and apertural ends. × 50. P. 41103 (1, 2).
9. *Nodosaria subcanaliculata* (Neugeboren) var. *spinescens* nov. Side view of holotype. × 30. P. 41114.
10. *Pseudoglandulina tumida* sp. nov. Side view of holotype. × 40. P. 41121.
11, 12. *Quinqueloculina akneriana* d'Orbigny. Side views. × 50. P. 41125.

FIGURE C

1, 2, 3. *Nonion applini* Howe & Wallace. Side and apertural views. × 65. P. 41132 (1, 2).
4, 5, 6. *Nonion umbilicatulus* (Walker & Jacob). Side and apertural views. × 65. P. 41135 (1).
7, 8, 9. *Nonionella auris* (d'Orbigny). Side and apertural views. × 95. P. 41136 (1).
10, 11. *Nonionella sp.* Side views. × 95. P. 41138.
12, 13. *Cornuspira lewisensis* Beck. Side and apertural views. × 65. P. 41140 (1).
14, 15. *Discorbis chapmani* sp. nov. Dorsal and ventral views of holotype. × 95. P. 41146.
16, 17, 18. *Valvulineria barnardi* sp. nov. Side, dorsal and ventral views of holotype. × 65. P. 41149.
19, 20, 21. *Eponides umbonata* (Reuss). Ventral, dorsal and apertural views. × 65. P. 41153 (1).

FIGURE D

1. *Bolivinopsis expansa* (Plummer). Section to show initial planispiral coiling. × 65. P. 41156 (1).
2, 3. *Textularia oveyi* sp. nov. Apertural and side views of holotype. × 65. P. 41159.
4, 5. *Gaudryina* (*Gaudryina*) *ashfordi* sp. nov.
  4 = Section of a specimen to show initial triserial arrangement of chambers. × 65. P. 41163 (2).
  5 = Side view of holotype. × 65. P. 41163 (1).
6, 7. *Pseudoclavulina anglica* Cushman. Side and apertural views. × 45. P. 41164.
8, 9. *Verneuilina carinata* Hermes. Apertural and side views. × 65. P. 41165.

LIST OF SELECTED REFERENCES[1]

BAGG, R. M. 1912. Pliocene and Pleistocene Foraminifera from Southern California. *U.S. Geol. Surv., Prof. Paper No.* 513.

BECK, R. S. 1943. Eocene Foraminifera from the Cowlitz River area of Lewis County, Washington. *Journ. Paleont.*, **17.**

BRADY, H. B. 1884. Report on the scientific results of the voyage of H.M.S. 'Challenger' during the years 1873–6. Vol. 9 (Zool.): Foraminifera.

CUSHMAN, J. A. 1948. *The Foraminifera, their classification and economic use.* Harvard University Press.

ELLIS, B. F. & A. R. MESSINA. 1940 *et seq.* A catalogue of Foraminifera. *Amer. Mus. Nat. Hist. Publ.*

GALLOWAY, J. J. 1933. *A manual of Foraminifera.* Bloomington, Ind.

GLAESSNER, M. F. 1945. *Principles of micropalaeontology.* Oxford University Press.

HALKYARD, E. 1919. Fossil Foraminifera of the Blue Marl of the Côte des Basques, Biarritz. *Mem. Proc. Manch. Lit. Phil. Soc.*, **62,** (2).

International Rules of Zoological Nomenclature. 1926. *Proc. Biol. Soc.*, Washington, **39.**

LE ROY, L. W. 1948. The Foraminifer *Orbulina universa*, a suggested Middle Tertiary time indicator. *Journ. Paleont*, **22.**

MYERS, E. H. 1942. Biology of Foraminifera and their significance in Palaeoecology. *Trans. N.Y. Acad. Sci.*, (2), **4,** No. 6.

NATLAND, M. L. 1933. The temperature and depth distribution of some recent and fossil Foraminifera in the Southern California region. *Bull. Scripps Inst. Oceanogr.*, Tech. Ser. 3, **10.**

NORTON, R. D. 1930. Ecological relations of some Foraminifera. *Bull. Scripps Inst. Oceanogr.*, Tech. Ser. 2, **9.**

SCHENCK, E. T. & J. H. MCMASTERS. 1948. *Procedure in taxonomy.* Revised and re-written by A. M. Keen and S. W. Muller. Oxford University Press.

SHERBORN, C. D. & F. CHAPMAN. 1886. On some Microzoa from the London Clay exposed in the drainage works, Piccadilly, London, 1885. *Journ. Roy. Micr. Soc.*, London, (2), **6.**

WISEMAN, J. D. H., & C. D. OVEY. 1950. Recent investigations on the deep-sea floor. *Proc. Geol. Assoc.*, **61,** (1).

WRIGLEY, A. 1924. Faunal divisions of the London Clay. *Proc. Geol. Assoc.*, **35,** (3).

---

[1] The list of references is intended to represent the very large field of papers and books consulted in this work, and is in no sense complete.

54 *Nodosaria ovulata*																				X								
55 *Nodosaria pariana*																				X								
56 *Nodosaria soluta*																				X								
57 *Quinqueloculina arctica*																				X								
58 *Quinqueloculina imperialis* var. *port.*												X	X	X	X	X	X			X								
59 *Quinqueloculina ludwigi*										X	X	X	X		X	X	X	X	X	X								
60 *Nonionella auris*																				X								
61 *Nonionella jacksonensis*																				X								
62 *Nonionella* sp.																				X								
63 *Globulina gibba*																				X								
64 *Discorbis champani* sp. nov.						X	X	X	X	X		X				X		X	X	X								
65 *Gyroidina soldanii*																				X								
66 *Eponides umbonatus*																				X								
67 *Bolivinopsis carinata*																X		X		X								
68 *Textularia lontensis*																		X		X								
69 *Textularia oveyi* sp. nov.																				X								
70 *Pullenia quinqueloba*												X		X		X	X	X	X	X	X							
71 *Nonion umbilicatulus*								X			X		X		X	X	X	X	X	X	X		X					
72 *Bolivinopsis expansa*								X				X	X	X	X	X	X	X	X	X	X		X	X				
73 *Bulimina ovata*			X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				X			

Nonionella jacksonensis	61
Nonionella sp.	62
Orbulina universa	38
Pseudoglandulina laevigata	18
Pullenia bulloides	7
Pullenia quinqueloba	70
Pullenia quinqueloba var. *quadriloba*	8
Pullenia salisburyi	9
Pullenia trinitatensis	10
Pyrulina gutta	23
Quinqueloculina akneriana	19
Quinqueloculina arctica	57
Quinqueloculinaim perialis var. *port.*	58
Quinqueloculina ludwigi	59
Textularia lontensis	68
Textularia oveyi	69
Uvigerina aculeata var. *asperula*	3
Uvigerina canariensis	4
Uvigerina jacksonensis	5
Valvulineria byramensis	25

[*To face p.* 174

Field Meeting in the Hindhead Neighbourhood

9 May 1953

Report by the Directors: J. F. KIRKALDY and F. A. MIDDLEMISS

Received 18 December 1953

THE MAIN OBJECTS of this Field Meeting were to demonstrate the succession of the Lower Greensand around Godalming and Hindhead and to discuss the structural conclusions reached by Mr. Middlemiss as a result of detailed mapping around Hindhead.

The coach drove down the Portsmouth Road to the Hogs Back, where a stop was made to indicate the chief features of the extensive view. Typical Folkestone Beds were then seen in the golf links pit (937.477) by the 'Jolly Farmer', Puttenham, and the coarse, pebbly, slightly fossiliferous facies of the Bargate Beds was examined at Frith Hill, Godalming (968.450). Continuing southwards, a brief halt was made to examine the Puttenham Beds in the Cemetery pit (940.416), Milford. The sands are much more extensively current-bedded than is usual in the Puttenham Beds, but they show the characteristic abundance of flakes and small pebbles of limonite. The route to Brook then crossed the axis of the Thursley syncline, typically asymmetrical, with a steeply dipping southern limb, which has been traced for nine miles from Great Enton, near Witley, to Headley. Time did not permit a halt at the good exposure (930.387) of the upper part of the Hythe Beds opposite the entrance gates of Witley Park. After lunch at the 'Dog and Pheasant', Brook, the party visited, by courtesy of Messrs. F. Milton & Sons, the nearby brickworks (931.379), which showed the silts of the basal Hythe Beds passing down into the Atherfield Clay and also some scattered exposures of Weald Clay from which ostracods, *Neomiodon* sp. and poorly preserved gastropods were obtained. The coach then drove back to the Portsmouth Road and ascended the long dip-slope to the head of the Punch Bowl. The party climbed to the top of Gibbet Hill (900.360), but unfortunately visibility was rather poor. Mr. Middlemiss stated that mapping of the Hythe–Atherfield junction in the Devil's Punch Bowl and the other valleys surrounding Gibbet Hill had confirmed that the Hindhead mass is anticlinal in structure, the axis of the anticline passing more or less beneath Gibbet Hill and plunging very steeply westwards, so that the base of the Hythe Beds was at 660 ft. in the valley between Gibbet Hill and the Inval Ridge to the south-east, 615 ft. at the head of the Punch Bowl, 540 ft. at Hindhead cross-roads, and well below 479 ft. at Grayshott Hall, two miles to the west. Thus Hindhead is an anticline showing uninverted relief, a dome-like structure still in a comparatively early stage of dissection, contrasting completely in this respect with the Fernhurst Anticline to the south. (See Fig. 1.)

A point of especial interest in the structure here lies in the fact that Hindhead forms part of one of the three great right-angled bends in the outcrop of the Hythe Beds, the other two of which are at Leith Hill and Hascombe. Superficially, these three features are so similar as to lead to the supposition that there must be some essential similarity in their structure, but in fact hardly a structural element in common has so far been found by the various geologists who have worked on these areas. At Hindhead the change of strike of the Lower Greensand from east–west to north–south is no doubt due to the presence of the steeply plunging Hindhead Anticline flanked on the south by the Haslemere Syncline, giving a structure similar to that at Gatcombe in the Isle of Wight, where the Chalk outcrop is similarly angulated, but this does not explain either the very sharp nature of the right-angled bend at Blackhanger (902.375), near Hindhead, or the strikingly anomalous uninverted relief of the Hindhead massif. The latter may possibly be due to lithological causes since the Hythe Beds at Hindhead are unusually thick (300 ft.) and of a resistant nature, containing much interbedded chert and cherty sandstone, compared with 180 ft. at Thursley, 2½ miles to the north—a remarkably rapid increase. This cherty facies of the Hythe Beds is also a rather sudden development; at Godalming, the Hythe Beds contain no stone, but the stony facies comes on above the sands to the south and thickens rapidly at the expense of the lower sands, true cherts coming in only to the south-west of Brook.

In connection with the sharp nature of the right-angled bend at Blackhanger, Prof. Wooldridge (1950) points out that there appears to be a 'step-up' of levels in the Hythe Beds as the line of the east–west scarp through Brook is continued westwards until it cuts the north–south part of the scarp near Blackhanger, and he therefore suggests a north–south line of dislocation of some sort running roughly along the line of the Cosford stream. Detailed mapping of this part of the area has not revealed any evidence of such a break, but on the other hand it appears that the Hindhead Anticline does not run exactly east–west but nearer to ESE.–WNW., so that stratum-contours drawn for the base of the Hythe Beds would run somewhat obliquely to the east–west Sandhills–Brook escarpment. Thus, if the line of this escarpment be extended westwards, the extension will cross successive stratum-contours, and at the point where the Portsmouth Road crosses this line, for example, corresponding levels in the Hythe Beds will be considerably higher than east of Blackhanger.

The effects of large-scale landslipping were also pointed out. All around

Gibbet Hill, the Hythe Beds have been very much affected by the collapse of the clay beneath, and the immediate view from the summit presents the unmistakable aspect of landslip topography. Prof. Wooldridge has adduced reasons for considering these large slips to be of Pleistocene age (*loc. cit.*). Superficial movement of a type similar to cambering has also affected the beds, since, in Boundless Copse, stone-bands are clearly exposed dipping eastwards towards the clay. Along the ridge traversed by the Portsmouth Road, above the Devil's Punch Bowl, the beds exposed dip eastwards on the east side of the ridge and westwards on the west side. In the Punch Bowl, too, a very great deal of slipping and general downhill movement of the Hythe Beds has taken place so that the clay outcrop is almost completely masked by sandy material not *in situ*.

From Hindhead the party drove northwards along the Tilford road and visited the section behind Stock Farm, Churt (877.384), described by Richardson (1947). After tea at the 'Pride of the Valley', where the President proposed the customary vote of thanks, the party climbed the Devil's Jumps (870.395) for an extensive view and also to see the unusually massive development of ironstone in the Folkestone Beds. The route next lead past Tilford and Crooksbury Hill to Runfold, where a brief halt was made to visit exposures in the Chalk (862.479), showing strike-faulting and considerable thrusting and shattering of the flints. The return to London was made via Ash, Bagshot and Staines.

REFERENCES

RICHARDSON, J. A. 1947. Chert formation in the Bargate Beds of the Churt Neighbourhood, Surrey. *Proc. Geol. Assoc.*, **58**, 161–77.

WOOLDRIDGE, S. W. 1950. Some features in the structure and geomorphology of the country around Fernhurst, Sussex. *Proc. Geol. Assoc.*, **61**, 165–90.

Field Meeting, Whitsun 1953, at Lynton, North Devon

Report by the Directors: SCOTT SIMPSON and C. KIDSON

Received 17 February 1954

THE LAST OCCASION on which the Association visited the Lynton area was at Easter, 1910, when one day was spent along the coast under the leadership of J. G. Hamling (*Proc. Geol. Assoc.*, **21**, pp. 466–8). During the course of the present Field Meeting some of the same ground was covered, but, in addition, inland sections were visited and attention was primarily directed to morphological problems and their bearing on the catastrophic floods of 15 August 1952.

Friday (evening), 22 May

The party, consisting of twenty-three members, assembled at Lynton and the Directors outlined the geology and geomorphology of the area to be visited. A series of fine aerial photographs, taken by the R.A.F. immediately after the flood, was displayed by Mr. Kidson.

Saturday, 23 May

The party descended by the cliff-railway, and, after examining slates of the Lynton Beds exposed behind the Promenade, made its way through the badly damaged village of Lynmouth. Although the huge accumulation of boulders, which had filled the streets, had been removed and a channel had been cleared for the river by bull-dozers, a vivid idea of the destruction caused by the flood was obtained from the red flood-level marks and the damaged houses. After visiting the site where ten houses had been washed away at Middleham, on the East Lyn, the party returned to the centre of Lynmouth and entered the West Lyn valley. Descending to the river from the road at a point 300 yds. above its confluence with the East Lynn, it was possible to appreciate the immense amount of talus which had been swept away as the stream undermined its banks. Active members climbed on the boulders which had been moved by the flood. Many of these were five or six feet in diameter. Sections in the Lynton Beds here, and by the roadside above, showed the peculiar U-shaped burrow with compressed cross-section which is comparable with *Arenicolites subcompressus* (Eichwald) of the German Rhaetic.

The gorge-like valley of the lower West Lyn was followed as far as Barbrook, where the knick-point marking the head of rejuvenation is situated. The position of Barbrook on the last terrace remnants of the pre-rejuvenation flood-plain was studied and the relation between the flood-damage and the damming of the river by débris lodged against the bridge was discussed.

From Barbrook the road on the east side of the West Lyn valley was followed to Sparhanger where a descent to the stream was made. Here the typical middle-reach flood-plain was well seen and the alluvial gravel was examined.

The return to Lynton was made over Lyn Down along the divide between the West Lyn and Hoaroak Waters. At Summer House Hill the view into the lower reach of the East Lyn below Myrtleberry Cleave revealed its similarity to the lower reach of the West Lyn.

Sunday, 24 May

As the tide was low it was decided to attempt to reach Sillery Sands from Lynmouth along the foreshore. Conditions, however, were not quite right, so, after proceeding far enough to obtain an idea of the tight recumbent folding of the Lynton Beds in the cliff east of Lynmouth, the party returned to the Manor House and climbed Countisbury Hill. After crossing Wind Hill the descent was made to the East Lyn at the foot of Chisel Combe. Here the effect of the great Brendon fault, which brings in the Foreland Grits on the north side of the valley, was well seen. It was noted that the Foreland Grits give rise to characteristic screes on the valley-side. The fault itself was seen exposed in the road-cutting below Watersmeet and again in the river-bank above Watersmeet. Continuing along the south bank of the East Lyn, the head of rejuvenation was reached at Brendon.

Above Brendon the broad flood-plain was compared with that of the West Lyn above Barbrook and the valley-side was ascended for a general view from a high-level terrace.

A coach then carried the party from Brendon to Hillsford Bridge, whose situation, approximately at the head of rejuvenation, resembles that of the bridges at Barbrook and Brendon.

Monday, 25 May

The party went on foot to Castle Rock in the Valley of Rocks where Dr. Simpson expounded his theory (*Proc. Geol. Assoc.*, **64**, pp. 14–23) of the rejuvenation of the Lyn drainage by a series of captures effected by the sea along a young fault-line coast. Such a capture at Wringcliffe Bay was responsible for the rejuvenation of the valley at this point, and a later one, at Lynmouth Bay, left the Valley of Rocks without a river. Following some discussion active members of the party descended to the shore by a steep cliff-path located on the fault responsible for the gap on the east side of Castle Rock. The lithology of the lowest Lynton Beds was examined in the cliff and the rest of the party was rejoined after ascending the cliff behind Wringcliffe Bay.

Continuing westwards, a second fragment of rejuvenated dry valley was traversed on the way past Lee Abbey to Lee Bay. In Lee Bay further cliff-sections in the Lynton Beds were examined and the prevalence of the branching sandstone fossils (so-called fucoids) in the slate was noticed. Thence the party followed the road to Woody Bay, stopping at the roadside quarry above Crock Point where good specimens of *Spirifer paradoxus* were obtained. The valley-floor remnants at Crock Point and Woody Bay Manor were noted, and the similarity of the hog's-back cliff-slopes to those of the rejuvenated valley-sides were remarked upon.

Thence the party proceeded along the path just above the cliffs to Heddon's Mouth and up the Heddon valley to Hunter's Inn. It was seen that the Heddon valley had experienced similar rejuvenation to that of the Lyn, but that the lower reaches were approaching grade with incipient flood-plain development. From Hunter's Inn a coach conveyed the party, via Trentishoe Down, Stoney Corner and the Parracombe by-pass, to the large Beacon Hill Quarry. On the by-pass the breach in the railway embankment caused by the piling up of the flood-waters was well seen. The quarry provided a fine section in the Hangman Grits.

Tuesday, 26 May

The long coach-tour over Exmoor left Lynton on the Simonsbath road. The first halt was made at Scob Hill where the degraded cliff-line at the back of the Lynton Surface was well seen. Good views across the Lynton Surface to the Exmoor Surface sky-line of the Chains were obtained from the coach as it travelled southwards.

At Blackpit Gates the party left the coach and walked up the Exe valley to the col on Exe Plain between the Exe and Hoaroak valleys to see the striking elbow of capture where the Hoaroak Water has intercepted the headwaters of the Exe. The return to the coach was made via a detour to Exe Head, where the black Galloway cattle, now reared on Exmoor, were seen, and whence a view across the Barle valley was obtained.

From Prayway Head the party went on foot downstream as far as Raven's Nest. The large-scale soil-slips that had taken place on the steep southern valley-side during the storm of August 1952 were visited. The Ilfracombe Slates were well exposed in the slip-scars and showed well-developed vertical cleavage. It seemed clear that the marked asymmetry of the Exe valley here could not be explained structurally.

Proceeding to Kinsford Gate, where Mr. Kidson gave a greatly appreciated account of the pioneering work of the Knights in the enclosure and farming of Exmoor, a splendid view of the country south of Exmoor was obtained. Thence the coach returned through Simonsbath, where flood-damage was noted, and proceeded to the vicinity of Red Stone Hill where the party again descended on foot into the Exe valley.

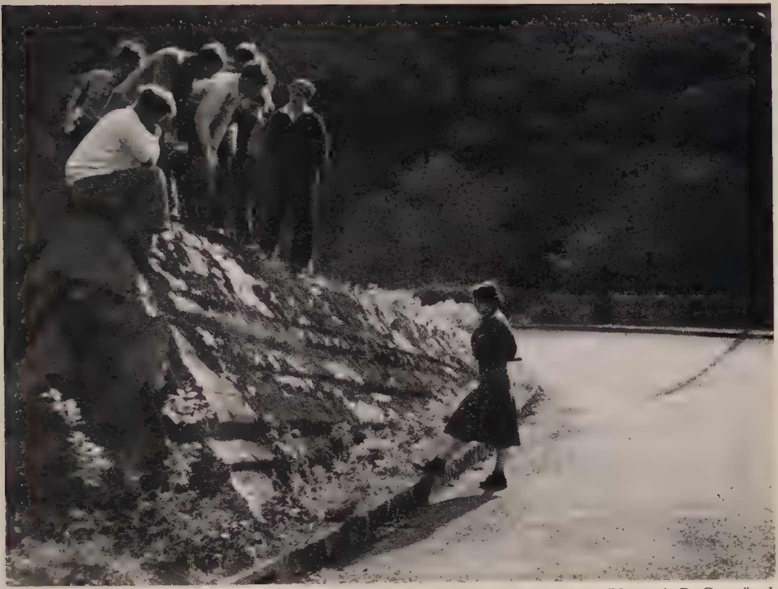


Photo A. R. Crawford

A. Stepped surface, Anthony's Quarry, Dulverton

Photo A. R. Crawford

B. Lynmouth and Lynton

On the flank of Red Stone Hill a high-level terrace was visited and Mr. Kidson gave an account of his mapping of the terraces of the upper Exe valley. Rejoining the coach the journey into Dulverton was made over Winsford Hill. In Dulverton the flood effects were explained and the flood-plain of the River Barle was examined.

Thence the coach followed the Exe valley to Wheddon Cross. On the way a halt was made at a bend in the road (Anthony's Quarry) one and a half miles above Hele Bridge. Here, what appeared to be deep parallel grooves in the Pickwell Down Sandstone rock-face by the roadside (Plate 2) were examined. These have been explained as glacial grooving, but a thin film of vein-quartz present within the grooves, and on the rock-face generally, eliminates this possibility. The quartz shows slicken-sliding inclined in the same direction as the 'grooves' but much more steeply. The 'grooves' were found to be parallel with the intersection of the bedding with the rock-face and Dr. Simpson suggested that the rock-face represented a gaping joint or fault-plane, and that, in a distant period of earth-movement, crustal stresses had been relieved by bedding-plane slip, successive beds sliding one over another to project into the gap. Such an explanation is comparable with one which has been given for the step-like breaking up of the pre-Rhaetic erosion surface of the Carboniferous Limestone in Gloucestershire (Whittard & Hudson, 1939). The direction of stepping is consistent with this explanation, and the party seemed satisfied with it.

The last stop of the day was made near the summit of Dunkery Beacon. Magnificent visibility allowed the eye to follow the Somerset coast to beyond Weston-super-Mare and the Welsh coast from Swansea Bay to Barry.

EXPLANATION OF PLATE 2

A. Stepped surface, Anthony's Quarry, Dulverton. The apparent grooving is due to slip on the bedding-planes (dipping steeply towards the left) in the massive Pickwell Down Sandstone. The ends of the beds at a major joint surface are stepped over one another towards the right.

B. Lynmouth and Lynton. The view shows the position of Lynmouth within the narrow, juvenile valley of the East Lyn, and of Lynton, above, at the beginning of the Valley of Rocks through which the Lyn flowed before marine erosion led to the capture at Lynmouth. The upper hog's-back cliff-slope on the right side of Holiday Hill (centre background) may be compared with the slope of the valley-side on the left of the picture.

REFERENCES

Simpson, S. 1953. The development of the Lyn Drainage System and its relation to the origin of the coast between Combe Martin and Porlock. *Proc. Geol. Assoc.*, **64,** 14–23 (and references).

Whittard, W. F. & F. G. Hudson. 1939. An interpretation of certain reversed faults at Chipping Sodbury, Gloucestershire. *Geol. Mag.*, London, **76,** 314–16.

Field Meeting at Whitecliff Bay, Isle of Wight

Sunday, 31 May 1953

Report by the Director: DENNIS CURRY

Received 10 December 1953

THIRTY MEMBERS and friends assembled at Waterloo, and proceeded to Portsmouth Harbour, where they were joined by ten more. A short sea-trip brought them to Ryde, after which they proceeded to the Whitecliff Bay Hotel by private coach.

The party assembled on the cliff-top, where the Director described in outline the geological structure of the Isle of Wight, and its relation to the rest of the Hampshire Basin. He pointed out that the cliff-section, stretching from Culver Cliff to Bembridge, was probably the finest and most complete single section of the Lower Tertiary beds in Europe, including, as it did, almost the whole of the Eocene and an appreciable part of the Oligocene, with few gaps in the succession.

He mentioned, too, its great importance in the correlation of the various marine Eocene Beds in England, and as a key to the relative age of the geographically separated fossil-horizons of Barton, Selsey, Bramshaw and Brook, and the London Clay.

As a source of nummulites, also, it was of great importance. Seven different species were to be found at various horizons and these were of great value in correlating the sequence with those of Belgium and northern France.

The party then proceeded down the cliff-path, and walked southwards along the shore to the north-eastern face of Culver Cliff, formed by a weathered dip-slope of the *mucronata* Zone of the Upper Chalk. The rock was rather hard, and fossils were not plentiful, but a few tests of *Echinocorys* were found.

From the most seaward point of the cliff, there was a magnificent view of the highly inclined sequence of Eocene Beds, and of the northern limb of the Isle of Wight monocline, which carries the Bembridge Limestone from a dip of some 30° at the top of the cliff, almost to the horizontal at the base of the cliff a quarter of a mile to the north. (See Plate 3.)

The junction of the Chalk with the sandy base of the overlying Reading Beds was found after some digging, the basal sand being full of broken but unworn flints. The continental purple, red and green clays of the main mass of Reading Beds received little attention and the party then examined the London Clay Basement Bed, with its abundant glauconite and red 'pebbles' of derived Reading Clay. High up the cliff, a seam full of tubes of the worm, *Ditrupa*, was located and some members took samples. The main mass of the London Clay, and of the overlying Bagshot Sands, were uninteresting from a collecting point of view, but were discussed as an example of a sedimentary cycle, terminated by the strong pebble-bed at the base of the Bracklesham Beds.

The Director stated that this latter series had been described in detail by Fisher (1862). It formed a more or less homogeneous sequence of marine beds, with minor pebble-beds, and one, perhaps continental, interlude, and was the representative of three French Eocene time-divisions, the Cuisian, Lutetian and Auversian (Lower Bartonian) respectively. The existence of the Lutetian and Auversian Beds had been known for a hundred years, but it was only comparatively recently that Wrigley and Davis (1937) had demonstrated the existence of a Cuisian fauna also in the Whitecliff Bay section.

At this point, the late Mr. Arthur Wrigley gave an account of the discovery and of its importance to an understanding of the relation between the English and French successions.

A brief account was also given of the occurrence and characters of the various species of nummulites to be found in the Bracklesham and Barton Beds, and the party then moved along the cliff-face, examining each horizon in turn. It was explained that the nummulites of the Cuisian fossil-horizon (Fisher's Bed IV) were not readily to be found by collecting from the exposed face. In fact, the party only discovered two specimens in all. The way to collect these nummulites—*N. planulatus* (Lamarck) and *N. lucasianus* (Defrance *in* d'Archiac)—was by sifting the fresh dried clay in bulk under water. A fair number of poorly preserved Mollusca, including *Venericardia*, *Turritella* and *Corbula*, were, however, obtained.

A short distance above the Cuisian fossil-bed, the so-called 'Coal Bed' was well seen. It is a brown lignitic deposit resting on a grey-brown clay, which is penetrated by roots. The Director mentioned that he had recently found a well-preserved dicotyledonous leaf, now in the British Museum (Natural History), at about 18 ft. above the 'Coal'.

The next fossiliferous marine division (Fisher's Beds VI, VII and VIII) is referred to the Lutetian on the strength of the presence of *Nummulites laevigatus* Lamarck and the associated Mollusca. The nummulites were extremely abundant in Fisher's Bed VII, and many samples were taken. According to Abrard and Morellet (1937), *Nummulites aquitanicus-girondicus* Benoist also occurs at this horizon. *Nummulites laevigatus* was also found in Fisher's Bed VIII, and the Director reported that, by washing and sifting, he had obtained a few specimens of another nummulite from the horizon; possibly a dwarfed form of *N. variolarius* (Lamarck).

From this point, the party moved to the Upper Bracklesham Beds exposed between the two refreshment huts, and the beds equivalent to those at Brook and Bramshaw in the New Forest were pointed out. The exposed surfaces were not in a good state for collection, but a few small Mollusca were found. The Bramshaw horizon (Fisher's Bed XVII) was seen to be crammed with *Nummulites variolarius*, which is so common that hand specimens of the clay often appear gritty with its plump little tests; and once more, collecting bags appeared to good purpose. After a traverse of a short unfossiliferous section, the *Nummulites prestwichianus* Sand, which by definition marks the base of the Barton Beds, was found, and a few feet higher up, immediately south of the cliff steps, *N. rectus* Curry was seen.

Bidding farewell to nummulites at this point, the party passed by the remainder of the Barton series, pausing only to note a well-marked pebble bed in the Upper Barton Sands.

The greenish clays of the Lower Headon Beds were seen to contain freshwater shells, and a little digging exposed the junction with the overlying marine Brockenhurst Bed. Fossils were common, though ill-preserved in the latter, and a number of the characteristic molluscs including *Venericardia deltoidea* (J. Sowerby) and *Volutospina dunkeri* (Speyer) were found. About a hundred feet higher, the '*Venus*' Bed was seen, with a restricted estuarine fauna including abundant *Sinodia suborbicularis* (Goldfuss) (= '*Venus*'), *Potamides* cf. *vagus* (Solander), *Tritonidea labiata* (J. de C. Sowerby), *Cyrena* spp., and a suite of other fossils like those of the '*Venus*' Beds of Colwell Bay and Headon Hill.

Owing to lack of time, it was not possible to examine carefully the higher beds in the sequence, though individual members of the party got as far as the Bembridge Limestone before returning to the coach.

Tea was taken at the Royal Squadron Hotel, Ryde, after which the President, Dr. G. W. Himus, moved a vote of thanks to the Director, and the party dispersed.

REFERENCES

ABRARD, R. & L. MORELLET. 1937. Sur la présence de *Nummulites aquitanicus-girondicus* Benoist dans le Lutétien d'Angleterre. *C.R. Soc. Géol. France*, pt. 10, 133–5.

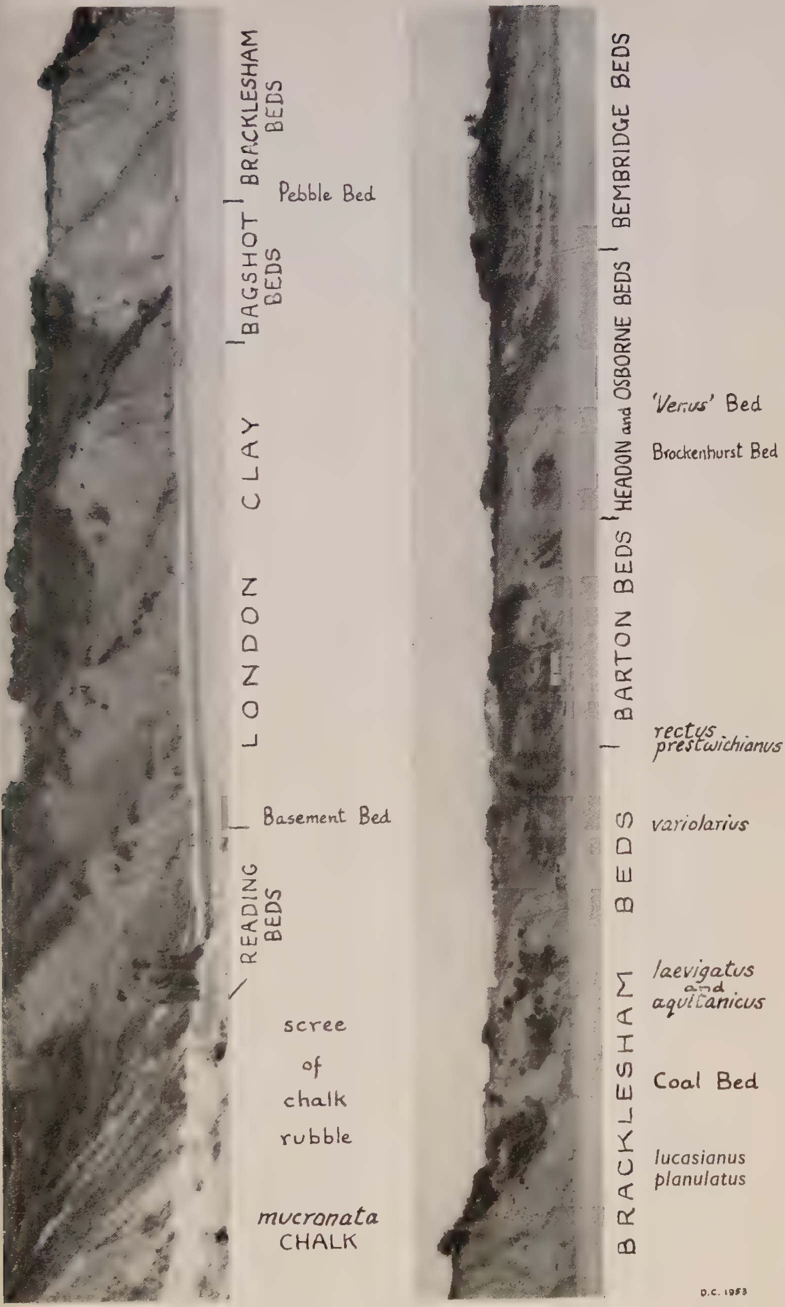
CURRY, D. 1937. The English Bartonian Nummulites. *Proc. Geol. Assoc.*, **48**, 229–46.

FISHER, O. 1862. The Bracklesham Beds of the Isle of Wight Basin. *Quart. Journ. Geol. Soc., Lond.*, **18**, 65–94.

WHITE, H. J. OSBORNE. 1921. The geology of the Isle of Wight. *Mem. Geol. Surv.*

WRIGLEY, A. & A. G. DAVIS. 1937. The occurrence of *Nummulites planulatus* in England. *Proc. Geol. Assoc.*, **48**, 203–28.

PLATE 3



Whitecliff Bay, viewed from Culver Cliff

[*To face p.* 184

The Lower Greensand in East Kent

by G. A. WORRALL

Received 7 August 1952

Read 3 July 1953

CONTENTS

1. INTRODUCTION ... ... *page* 185
2. STRATIGRAPHY 186
    (a) The Atherfield Clay 186
    (b) The Hythe Beds 187
    (c) The Sandgate Beds 190
    (d) The Folkestone Beds 192
    (e) The Junction Bed 194
3. STRUCTURE 195
4. MECHANICAL COMPOSITION 196
5. PETROLOGY 197
    (a) The frequency of the heavy-mineral species 197
    (b) The source of the Lower Greensand Beds in East Kent 198
ACKNOWLEDGMENTS 199
EXPLANATION OF PLATE 199
REFERENCES 199
DISCUSSION 200

SUMMARY: A field and laboratory study of the Lower Greensand of East Kent has been made. Doubt is cast on the existence of the Atherfield Clay along parts of the outcrop. The rag and hassock of the Hythe Beds is thinner than formerly estimated, and disappears almost as soon as it passes under younger beds. In the west chert and red sand occur on high ground. The Sandgate Beds show a regular lithological sequence of which a mottled silt is dominant, but there is considerable fluctuation in the thickness of the beds. The Folkestone Beds are more uniform in thickness and composition, and the Junction Bed at the top is well exposed.

The area is structurally simple, the regional dip of 1–2° being only occasionally disturbed, as at Sandgate. A long strike-fault is postulated to account for the outliers of Hythe Beds to the south.

Mechanical and mineralogical analyses have been made, the latter indicating differences in the heavy-mineral composition between the Hythe Beds and the higher beds, and the source of the sediments is discussed.

---

1. INTRODUCTION

THE AREA of Lower Greensand studied occupies a narrow belt some two to three miles wide and twenty-five miles long from Folkestone in the east to Harrietsham, near Maidstone, in the west. It forms a line of low hills of heights ranging from 200 ft. O.D. in the east to 500 ft. in the west, bisected at Ashford by the River Stour. Of the four divisions of the Lower Greensand, the Hythe Beds, because of their stone-bands, form a steep escarpment facing south-west; the Folkestone Beds form rather lower hilly ground and cut deep valleys. The Atherfield Clay and Sandgate Beds, being composed of clay and silt, occupy low ground, except where gravel-capped (see Fig. 1, p. 194).

Work on this area has been confined mainly to the classic coastal section between Hythe and Folkestone which has been studied by Fitton (1836), De Rance (1868), Topley (1875), and Price (1875), and more recently by Spath (1923–43, 1930, 1935) and Casey (1939, 1950).

By comparison, the references in literature to the inland area are few and mostly cursory. Early references were those of Packe (1743), Smith (1819) and Fitton (1836), and a fuller account came with Topley (1875). Gregory (1895) described the fauna at the base of the Sandgate Beds at Great Chart, and Cornes *et alii* (1925) covered the geology of the Ashford area. Subsequently Cornes (1928) published a summary of the knowledge of the Lower Greensand of East Kent together with further results of his investigations and, more recently, brief references have been made by Kirkaldy (1937) and Casey (1939).

There has been very little laboratory work done on these beds. Hinde (1885) studied the rocks of the coastal sections for their content of sponge-spicules. Cornes reported on a thin section of ragstone, and several chemical analyses of the ragstone and hassock have been made.

2. STRATIGRAPHY

(a) **The Atherfield Clay.** This division was mapped as a continuous outcrop throughout the area by Drew, and its presence recorded at Hythe by Simms (1843) and at Court-at-Street, three miles inland, by Fitton (1843). Later it was found north of the area in several coal-borings, e.g. at Brabourne. The accounts of its lithology both in this district and elsewhere show considerable variation in colour and texture, but most usually it appears to be chocolate-brown or blue, sometimes with calcareous nodules, and containing more silt and fine sand than the Weald Clay.

The formation is very poorly exposed in this area. The coastal section, seen by Topley at very low tides, is not now visible, and further search revealed only one exposure which could certainly be referred to Atherfield Clay. This section in the railway cutting at Mersham (051.393) shows the base of the Hythe Beds passing down into the Atherfield Clay below:

Soil … … … … … … … … …	10 in.
Reddish-brown coarse sandy loam with blackish iron oxide at the base … … … … … … … … …	14 in.
Greenish hassock … … … … … … …	18 in.
Black and brown mottled horizon … … … … …	6 in.
Pale grey silt, mottled orange … … … … …	4 ft.
Very pale, almost white, silty clay becoming heavier at depth …	10 ft.
Medium grey clay which crumbles into cubical lumps … …	2 ft.

This description shows a close similarity to that given by Gossling

(1929) in the Reigate area and also to that at Leeds (538.828), near Maidstone, where a mottled silt followed by a blue-grey silty clay (Fuller's Earth) underlies the Hythe Beds. By augering, a grey silty clay above a brown clay was observed at Boughton Malherbe (493.885), and a chocolate-coloured clay was seen at Aldington (060.372), but elsewhere the Hythe Beds were found to be underlain by a grey, somewhat rusty, clay characteristic of the Weald Clay. This is in accordance with the experience of Cornes, who found Weald Clay immediately beneath the Hythe Beds at Smeeth, and with a suggestion made by Topley (1872) that the Atherfield Clay is not always present, and the conclusion seems inevitable that it must either be discontinuous or not always lithologically distinct in this area.

(b) **The Hythe Beds.** At the present day the Hythe Beds are well exposed, since the ragstone is being increasingly quarried for road-metal. They are consistent in lithology throughout the area, being made up of seams of ragstone alternating with hassock, as described by Topley (1872, pp. 116–18). Though the proportion of ragstone to hassock is not constant, it is usually about three of ragstone to two of hassock, with a rather greater proportion of ragstone in the east. Towards the base of the Hythe Beds the ragstone disappears or becomes lenticular, the lowest 10–12 ft. being mainly or entirely hassock.

The ragstone has a uniform appearance. The colour is buff at the surface where it is in contact with the hassock, but on freshly fractured surfaces it is blue-grey. This varies in shade and is often very dark in the lower seams. It is a compact hard rock containing dark grains of glauconite and small glistening crystals of calcite. It is noticeably heavy. Estimates of the specific gravity gave an average result of 2.7—a figure near that of calcite (2.71). The percentage of calcium carbonate in the ragstone was found roughly by means of dilute hydrochloric acid, and was shown to be about 85%, most samples varying less than 5% from this (Table I, page 188). These results are surprisingly high for a rock which is generally known as a 'sandy limestone'.

Thin sections of ragstone indicate that it has a uniform composition. It consists of a groundmass of crystalline calcite in which are embedded angular quartz-grains (5–10%) and glauconite (1–2%). The calcite-grains have an average diameter of 0.06 mm. but may be aggregated into larger masses in optical continuity up to one millimetre. The quartz-grains are angular to sub-angular and evenly scattered through the rock. The few glauconite-grains are roughly rounded, and botryoidal or rod forms are usually absent, though occasionally Foraminifera and sponge-spicules may be seen infilled with a green pigment.

The ragstone is rich in Foraminifera, of which as many as twenty may occur on one slide. Dr. J. E. Prentice has kindly identified them as species of the following: *Textularia*, *Textulariella*, *Rotalia*, *Hemicristellaria*, *Cibicides* and small *Ammoglobigerina*-like forms. Some sponge-spicules and fragments of Polyzoa also occur.

The hassock is a loamy sand, containing much glauconite, together with some clay and silt, and a variable quantity of calcium carbonate. It is pale in colour, sometimes almost white, with dark grains of glauconite giving it a speckled appearance. A variation in the hassock has been seen at several points near the base of the Hythe Beds, and consists of a layer of several feet of dark green loamy sand. It seems likely that this is a constant feature of the basal Hythe Beds in this area.

Thin veins of a chocolate-coloured clay are often to be seen at the tops of quarries in the ragstone. The clay may be intermixed with hassock or line joint-faces if the ragstone, and occasionally it is seen as bands alternating with a pale sandy material and passing laterally into weathered ragstone. This is best seen in a small overfold in the quarry at Leeds (538.828), where the upper limb contains several layers of brown clay which pass abruptly into the ragstone in the lower limb. It is evident from this that the clay is a weathered product of the ragstone and the intermediate pale material is the weathered product of the hassock. But this cannot be the whole story as the mechanical analyses show that there is more silt and clay in the hassock than in the ragstone, while these weathered products show the reverse. As an explanation it is suggested that the ragstone, before the solution of the calcium carbonate, acted as an impervious 'illuvial' horizon upon which the clay, leached from higher horizons, was deposited, and this has tended to remain after the disappearance of the ragstone.

A variation in the lithology of the Hythe Beds occurs in the western part of the area, where lenticles of chert appear in the ragstone as thin, dark veins. These have long been recorded in the Maidstone area and westwards, but they extend eastwards into the area under discussion, dying out at about Lenham.

In addition to this kind of chert-development there are also chert-seams associated with a red loamy sand occurring above the rag and hassock in the west of the area. The chert is thin, dark and compact, and the associated 'hassock' is reddish-brown and non-calcareous—very different from the true hassock. The association of chert with a non-calcareous red loamy sand is a constant feature to be seen between Little Chart and Maidstone. The chert is very resistant to weathering and lies about on ploughed fields as slabby pieces of stone, and the soil is reddish and deep, quite different from the soil developed on the ragstone farther east. The chert-facies has been observed at only one place farther east than Little Chart—at Ninn Lodge quarry near Great Chart (975.427) where a little chert and red loamy sand is seen preserved in a subsidence-pocket, indicating that the chert-facies was once more extensive than it is now. Exposures at or near the escarpment in this western part of the area are singularly rare, but at Boughton quarries (Plate 4), a little outside the area under discussion, the chert-facies is well developed. Above the rag and hassock comes about 18 ft. of the chert and sand known locally as 'callow'. The facies closely resembles that occurring at Little Chart, but has in addition some almost white porous chert. The reddish sand is lightly cemented into a porous rock which is extremely light in weight.

In thin section the chert is seen to consist almost entirely of microcrystalline or cryptocrystalline silica. Detrital quartz-grains and glauconite are both rare, and calcite occurs only occasionally and then is very subordinate. Botryoidal and agate forms of chalcedony are common and there are also numerous small circular areas. These were at first thought to be transverse sections of sponge-spicules since they are of the right size and contain an inner canal-like area, but the almost complete absence of longitudinal sections suggests that they are actually spherical, and represent a mode of incipient crystallisation.

This chert and red loamy sand is best developed on the high ground. In the quarries down the dip-slope there is little or none to be seen, which suggests that it is not a stratigraphical facies of the Hythe Beds but a residual weathering product from which all calcareous matter has been leached and the iron compounds converted to ferric hydroxides. On the other hand, the reddened appearance of the junction of the Hythe Beds with the Sandgate Beds, which will be referred to later, indicates that this process may have at least begun before the deposition of the Sandgate Beds. The disappearance of the weathered product from the east of the area can be explained as being due to accelerated erosion in the absence of protective chert, and, in consequence, the Hythe Beds are lower in the east than in the west.

The Hythe Beds are rich in fossils which occur in both the rag and the hassock. They are, however, mostly long-range lamellibranchs of which *Exogyra sinuata* is the most common. The few ammonites found have kindly been identified by Mr. Casey, of H.M. Geological Survey, as follows:

Tropaeum cf. *gigas* (J. de C. Sow.) from Willesborough (045.412) (near the top of the Hythe Beds).
Deshayesites sp. from Mersham (056.393) (near the base).
Deshayesites cf. *deshayesi* (d'Orb.) *s.l.*, from Smeeth (063.368) (base).
The first and second belong to either the *deshayesi* or *martini* Zone, and the third to the *deshayesi* Zone in the scheme of zonal classification proposed by Spath.

Previous estimates of the thickness of the Hythe Beds have usually been between 60 and 80 ft., and this is in keeping with the observed dip and width of outcrop. But it is noteworthy that the quarry-depths are always considerably less than this, as the following show: Hythe, 20 ft.; Lympne 12 ft.; Otterpool Manor, 25 ft.; the deepest at Aldington, 16 ft. West of Ashford the depths are generally greater: Great Chart, 33 ft.; Little Chart, 45 ft. The quarries farther down the dip-slope are much shallower and it is possible that both here and in the eastern part the problem of drainage prevents deeper excavations. On the other hand, the statements of quarrymen all indicate that there is never much ragstone below the floor of their quarries, even of the shallow ones, and this has been substantiated in two quarries by deep augering. Nor is there much to be added to these thicknesses to allow for the eroded top of the Hythe Beds, for several of the quarries are at or near the junction with the Sandgate Beds.

Another peculiar feature of the rag and hassock is that it virtually disappears as soon as it passes beneath younger beds. It is, of course, well known that all the Lower Greensand beds thin out northwards, but in the case of the ragstone its disappearance seems to be almost coincident with the northern margin of its outcrop, a fact borne out by the following well and borehole records taken from *H.M. Geological Survey's Wartime Pamphlet* No. 10: Aylesford, Hythe Beds, 45 ft., of which one foot is ragstone; Little Chart, four wells with rag and hassock ranging from 8 to 28 ft. thick; Westwell (990.470), Hythe Beds and Atherfield Clay, 49 ft., including 1½ ft. of ragstone; Henwood (Ashford), Hythe Beds, 36, 24, 30, 37 ft. Whittaker (1908, p. 77) comments on these thicknesses; Willesborough, 250 ft. of Lower Greensand passed through, and should include at least some of the Hythe Beds, but no ragstone encountered; Brabourne, Hythe Beds not proved, and no ragstone encountered.

The extent of the Hythe Beds and their overstep by the Sandgate Beds in the Weald has been fully investigated by Kirkaldy (1937), who has given good evidence for a period of erosion following the deposition of the Hythe Beds. He does not, however, deal with the remarkable parallelism of the outcrop of the Hythe Beds and the northern limit of the rag and hassock. Cornes (1925) gave the opinion that the rag and hassock was a sedimentation-facies running near the Lower Greensand shore. If this is true it is a remarkable coincidence that erosion should have proceeded for so many miles parallel to that shore. Such an explanation would also be inadequate for the problem of the variation in thickness of the rag and hassock between high ground and low. A suggestion made by Wooldridge (see Kirkaldy, 1937, discussion) that the formation of the ragstone bands was in some sense a superficial effect, is an attractive one, though it is difficult to see how this could have been brought about, and it conflicts with the evidence for intraformational erosion.

(c) **The Sandgate Beds.** Although in places they are quite thick, the Sandgate Beds in East Kent are poorly exposed and the coastal sections, described by Topley, are now mostly hidden. Small exposures may be seen at a number of places but, except for a fine temporary exposure of the base of the beds at Sellindge, none is good.

There is considerable diversity of lithology, but repeated augering indicates that the following succession is relatively persistent throughout the area:

3. Fine sand, grey or mottled.
2. Pale silt or silty clay, with strong orange mottle.
1. Dark green clayey sand or sandy clay, the sand being coarse and sometimes mottled to a deep orange.

The fossiliferous nodules bed at the base of the Sandgate Beds has been observed only in two places, and, as Topley suggested, it is probably not persistent throughout the area. At Mersham (056.393) the base is seen with soft, phosphatic concretions, but no fossils have been found.

The succession at Great Chart is:

4. Dark grey-green clayey coarse sand, striated with white or buff material	3 ft.
3. Dark green sand with phosphatic nodules	3 in.
2. Orange yellow loamy sand	2 in.
1. Rag and hassock	15 ft.

A temporary road section some 40 yds. long of the Hythe–Sandgate Beds junction is exposed at Sellindge (107.375):

7. Soil	24 in.
6. Dark green clayey sand	28 in.
5. Nodules bed	5–9 in.
4. Dark green clayey sand	30 in.
3. Reddish-brown layer	4–14 in.
2. Rag	20 in.
1. Hassock	8 in.

The nodules are small (half to one inch in diameter) and persistent, but in places phosphatisation is incomplete and the nodules are soft. The fossils are mostly phosphatised but some are ferruginised or calcareous. They are restricted to this bed.

The ferruginous top to the ragstone is seen in both exposures, and appears to be a weathered surface, but it is not clear whether it is an intraformational effect or a recent one. It is difficult to see how the effect of weathering could penetrate the rather impervious Sandgate Beds which are undisturbed with their mostly fresh glauconite. On the other hand, the ochreous material passes up without a break into the green clayey sand—there is no erosion-surface.

The fossils of the Sandgate Beds at Great Chart and Sellindge appear to be restricted to the nodule bed, from which a number of brachiopods and lamellibranchs—all Hythe Beds forms—have been obtained. The palaeontology of this horizon and the Hythe Beds as a whole in this area are at present being investigated by Mr. Casey.

Besides showing a regular thinning from about Lenham westwards, the Sandgate Beds show fluctuations in width of outcrop in the rest of the area, which may be due to local variations in thickness or of dip. Estimates of thickness in the area mapped vary from about 120 ft. at Sellindge to 30 ft. at Hinxhill. Similar fluctuations in the thickness of the Sandgate Beds in the Hascombe area have been discussed by Kirkaldy (1932).

(d) **The Folkestone Beds.** Exposures of the Folkestone Beds are numerous in this area due to past and present digging of the sand, and the well-known section in the cliffs at Folkestone is only one of a number which show the main mass and top of these beds.

The broad lithological features have been described by Topley (1875) and Cornes (1925), who have shown that the Folkestone facies, well seen on the coast, dies out at Sandling, after which the normal sandy facies is developed, with a local development of chert at Eastwell Lane, near Ashford. In addition, there is a considerable development of ironstone in the Charing Heath area where it appears in the many exposures there as thin dark brown slabs lying in the bedding plane or false-bedding, or as boxstones which may contain a clean white sand. Pyritous concretions have been obtained from Brabourne.

The sands are always strongly current-bedded, the foresets being picked out by a variety of materials—glauconite, limonite, clay, micaceous clay, chert or ironstone—and the direction almost always to the south-east. Some variation of direction occurs in the Charing Heath area where south-westerly foresets are sometimes seen. The colours of the sands are most commonly either buff or nearly white, and where both occur, as in the Lenham–Leeds area, the buff is seen above the white. This is the only indication of a local succession except for the appearance of wisps of clay and much glauconite in the top few feet below the Junction Bed. Examination of hand specimens of the main mass of the sand show that quartz-grains with a little dark mineral occur most commonly, but with glauconite being frequently present and sometimes dominant. White mica, limonite, chert fragments, black shale and clay galls are commonly seen, while small pebbles of fine sandstone resembling the Wealden sandstones have been observed in the west of the area.

Thin sections of the rocks of the Folkestone Beds show that there is a considerable range in composition, extending from sandy limestones to lime-free cherty sandstones. Unlike the rocks of the Hythe Beds there is always a substantial proportion of detrital quartz in these rocks, but scarcely any fossils even in the calcareous types.

Two fairly distinct types occur, a dark, thick, calcareous sandstone, and a white, thin, cherty sandstone. Their difference as shown by thin section is mainly in the matrix, the one being of calcite, the other of silica, though most rocks contain some of both materials. The detrital grains are

TABLE II THE MINERALS OF THE LOWER GREENSAND OF EAST KENT – SUMMARY OF RESULTS

FORMATION AND GRADE	ZIRCON				STAUROLITE	RUTILE		TOURMALINE		GARNET		KYANITE	IRON ORES				MUSCOVITE	MONAZITE	SILLIMANITE	CHLORITE	TOPAZ	BROOKITE	ANATASE	APATITE	ANDALUSITE	HORNBLENDE	FELSPAR
	PRISMATIC	ROLLED	ZONED	PURPLE		RED	YELLOW	DUSKY	BLUE	COLOURLESS	COLOURED		ILMENITE & LEUCOXENE	MAGNETITE	PYRITE	LIMONITE											
HYTHE RAG	VR	A		ER	F	F	VR	F	VR	R/F	VR	R/F	A	F	R	F		ER	VR	VR	ER	ER	VR	ER	VR		ER
HYTHE HASSOCK (C)	R	A/F		VR	F	F	ER	A/F	VR	R/F	VR	F/R	A	F		F			VR	R						ER	ER
HYTHE HASSOCK (F)	R	A	VR	R	F/R	F	R	A/F	R	F	R/F	R	A	F		F	ER	VR	VR	VR	VR	ER					
SANDGATE BEDS	R	FL	R	ER	R	R/F	A/F	R/F				R	A/FL	F		R	R/F	ER	ER			VR	ER		ER		ER
FOLKESTONE BEDS (C)		F/R		R	F/A	R	ER	F/R			ER	A/F	A/FL	R		F	R/F		ER				ER		ER		
FOLKESTONE BEDS (M)	ER	F/A	ER	VR	F	F/R	ER	R/F		ER		A/F	A/FL	R		F	VR	ER	VR		ER		ER		VR		ER
FOLKESTONE BEDS (F)	VR	A/F	ER	VR	F	F/R	VR	R/F		ER		F	A	R		F	ER		VR		ER		ER		ER		

Frequency abbreviations: Fl = Flood; A = Abundant; F = Frequent; R = Rare; VR = Very rare; ER = Extremely rare large, mostly quartz, and make up a quarter to three-quarters of the rock. There are a few fresh glauconite grains, but most of them appear to have been altered to limonite, particularly in the siliceous types. In the calcareous rocks the calcite occurs as large optically continuous pieces up to 6 mm. in diameter, giving the rock in the hand specimen a lustre-mottling effect. The siliceous matrix is largely chalcedony, occurring as botryoidal and agate forms. It is frequently seen rimming the quartz-grains. There is some evidence of subsequent alteration in these rocks; veins of calcite may be seen occupying the space between fractured quartz-grains, the pieces remaining in optical continuity. Elsewhere, the reverse may be seen, i.e. chalcedony having eaten into the large plates of calcite.

The Folkestone Beds are fossiliferous only where phosphatisation or calcification has occurred. The ammonites found by Spath (1935) and Casey (1939, 1950), and used to zone the Folkestone Beds, came from the Folkestone Stone or from phosphatic nodules. West of Sandling the stone disappears and the only fossils found occur in the vicinity of the Junction Bed.

The beds are about 55 ft. thick on the coast, and become thicker towards the west. Calculations from widths of outcrop and amount of dip give a maximum figure of about 120 ft. Well records, however, indicate that thicknesses range from 85 ft. at Folkestone to 182 ft. at Aylesford, which suggests that the dip of these beds must be greater than the 1–2° shown by the Hythe Beds.

(e) **The Junction Bed.** The Folkestone Beds terminate upwards in the well-known Junction Bed, which has been described by several workers in the section at Copt Point, Folkestone. There are also several good exposures inland—Sandling (147.370), Sellindge (118.392), Brabourne (090.401), Willesborough (038.433)—and these differ in certain respects from the coastal section. At Folkestone the phosphatic nodules are black, with pyrite veining and encrusting them. Inland the nodules are whitened on the surface or sometimes throughout, and are smaller than those on the coast. They do not contain any visible pyrites, though they are usually associated with a sulphur-like material and limonite, which may be derived from pyrites, though analyses have shown that the yellow material consists of iron compounds, not sulphur. The general appearance of these inland sections is one of greater decomposition than that on the coast.

A distinct change of facies occurs at the base of the outliers of Gault between Hinxhill and Sellindge, where the phosphatic nodules of the Junction Bed have not been seen, though they are present in the main outcrop to the north. The bed is strongly ferruginous, and may contain ironstone, as in Quarrington Wood (057.417), and bears some similarity to the Junction Bed in West Sussex, described by Kirkaldy (1937).

Evidently there must have been a somewhat different environment of sedimentation in these areas.

The palaeontology of the Junction Bed has been investigated by Casey, who has shown that the lines of nodules may be of quite different ages, and that the bed does not indicate a break in the succession but a very condensed sequence.

3. STRUCTURE

The broad structure of the Lower Greensand in East Kent was shown by Topley to consist of a regional dip of 1–2°, upon which are imposed two gentle synclines running parallel to the dip and followed by the Rivers Stour and Medway. The only steeply-dipping beds occur in the Maidstone area where they are caused by the slumping of the ragstone.

In addition, there is a steeply-dipping area of Hythe Beds on the shore at Sandgate, mentioned by Fitton (1836) but not by subsequent geologists. The ragstone bands may be seen at low water from Shorncliffe almost to Sandgate, dipping at angles between 28° and 40° in directions varying between NNE. and N. They disappear at Sandgate Village and are not seen again for three-quarters of a mile, when they reappear at Mill Point with a normal low NE. dip. This disappearance of the ragstone approximately along the strike coincides with a slight embayment of the coast which in recent winters has suffered much from storm attack by the sea. It seems probable that there is a line of faulting here, or possibly extensive landslipping, though the ragstone appears too regularly disposed for this.

Faulting is not extensive in this area. Of those shown on the one-inch maps of H.M. Geological Survey, only the dip-fault at Summerhouse Hill (165.378) causes any large topographical feature, this being the projection of the Chalk escarpment southwards. Several other faults have been included in the area mapped by the writer,[1] none with any large throw. One running NE.–SW., and downthrowing to the east, throws the impervious Sandgate Beds against the Folkestone Beds and may be responsible for the marshland known as Gibbin's Brook (117.386). Another farther south (365.100) brings up Weald Clay against Sandgate Beds. A fault running NW.–SE. along the valley of the East Stour, between Mersham and Aldington, is postulated, since the base of the outlier of Hythe Beds at Clap Hill (060.370) is lower than a regional dip of one degree will allow. The discrepancy increases towards the north-west end, while farther west the outlier at Great Chart and neighbouring outliers are similarly lower than would be expected from a consideration of the regional dip. The dip of the beds is constant throughout so that the synclinal structure suggested by Topley (p. 235) is not feasible. A long strike-fault extending from Aldington to Hothfield would better explain the preservation of these outliers to the south of the main outcrop, though in the Ashford area the beds are complicated with other faults.

---

[1] The original six-inch maps of this area have been deposited at Wye College, Ashford, Kent.

Of the outliers marked on the geological map, that at Colliers Hill (038.388) was found to consist, not of Hythe Beds, but of a lens of non-calcareous fine sand probably belonging to the Weald Clay. The small outlier far to the south at Steed's Lane (007.380) also failed to reveal anything resembling Hythe Beds.

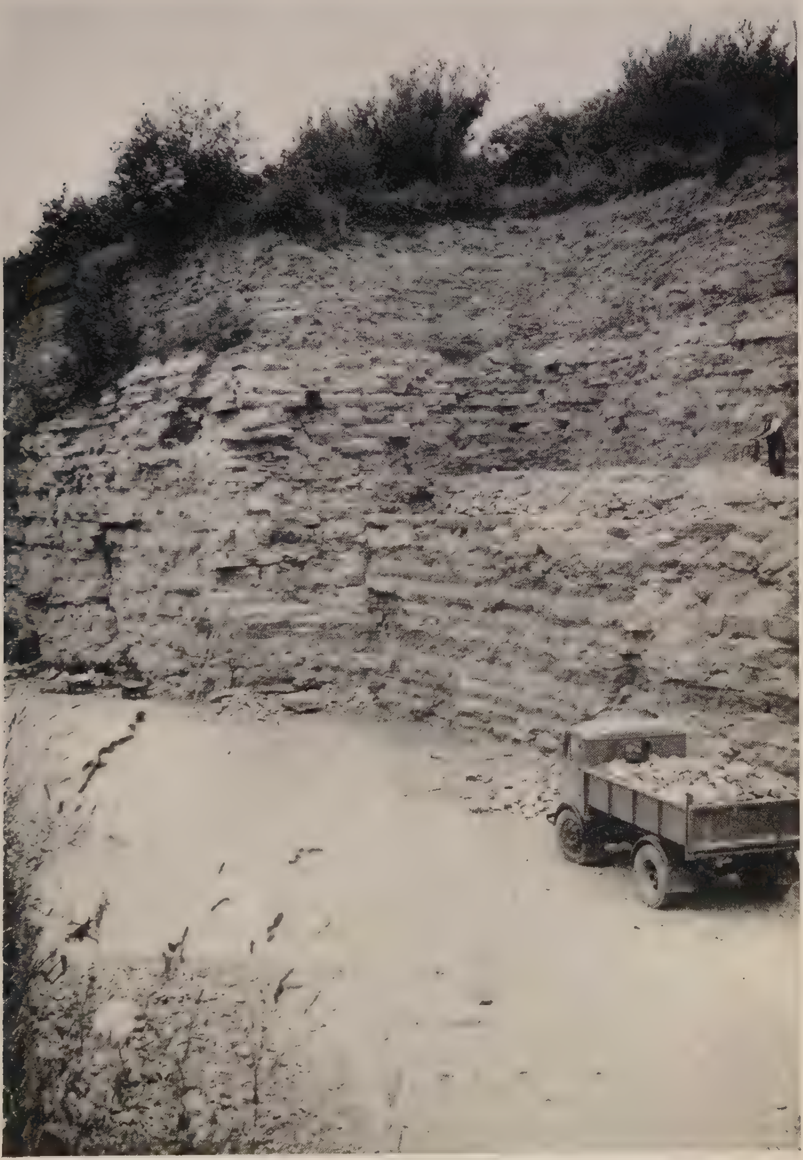
A structure believed to be superficial and associated with the Hythe Beds occurs in the Aldington area, where the Weald Clay is sometimes seen forming low rises which may be as high or higher than the neighbouring ragstone, as, for example, between Hungry Down and Bested Hill (083.374). These features are evidently due to the cambering of the heavy ragstone on the Weald Clay.

4. MECHANICAL COMPOSITION

Analyses were made of the ragstone, the hassock, the Sandgate Beds and the Folkestone Beds (Table I, p. 188). The ragstone is seen to consist of about 80–85% material soluble in dilute hydrochloric acid, and this is all calcium carbonate except for about 2% which consists of hydroxides of iron and aluminium. The non-soluble fractions are uniformly badly graded with a slight concentration in the fine-sand size. There is some variation with horizon; the topmost ragstone is less calcareous and more sandy while the basal layers contain less sand and more silt and clay, which may account for their darker colour. The hassock has a much lower and more variable content of calcium carbonate, which accounts for its uncemented or only partially cemented condition. The non-soluble fractions have a distribution very similar to those of the ragstone.

Analyses of the Sandgate Beds show that the composition varies with the horizon from which the samples are taken. The basal bed contains much clay, less silt, and much fine sand which is strongly glauconitic. The higher beds consist dominantly of fine to very fine sand with less glauconite but often with much mica. The grading varies from poor at the base to good at the top.

The Folkestone Beds show much more uniformity, being consistently medium to rather fine sands, with a silt and clay fraction generally less than 3%. The only exceptions come from the top of the succession, where a larger percentage of clay occurs. There is some variability in the grading. This is generally rather poor, with most of the sand-fractions represented and sometimes pebbles, but some samples show good grading, and these are frequently micaceous, as is the case in the Sandgate Beds.



Boughton Quarry, near Maidstone, showing about 18 ft. of 'callow' overlying rag and hassock.

5. PETROLOGY

Reference has already been made to the mineral composition of the Lower Greensand beds as revealed in the hand-specimen and by mechanical analyses, and it was shown that while quartz-grains are generally dominant, there are exceptions in the Hythe Beds where flaky chert-grains become dominant, and in the basal Sandgate Beds and parts of the Folkestone Beds where glauconite becomes most abundant. Muscovite is also a variable constituent and appears to have an antipathetic relationship with glauconite and limonite, being found with clean, well-graded, quartzose sand.

The heavy minerals usually form a very small part of 1% of the whole, and panning was necessary in most cases before separation with bromoform. Some seventy separations were made, and the heavy minerals mounted, examined and counted. A summary of the results is given in Table II, p. 193.

(a) **The frequency of the heavy-mineral species.** The average frequency of the heavy minerals in all the beds is as follows:

Frequent to abundant: ilmenite, leucoxene, zircon.
Frequent: staurolite, limonite, rutile, tourmaline, kyanite, magnetite, muscovite.
Rare to extremely rare: garnet, pyrite, felspar, monazite, sillimanite, chlorite, topaz, brookite, anatase, andalusite, hornblende.

There are differences in frequency and variety between the beds. The Hythe Beds are distinctive in possessing a higher content of tourmaline (especially the deep blue variety), and garnet, than the higher beds. They also contain chlorite, which is absent from the higher beds, and chert-grains are very common. The Sandgate Beds are very similar to the fine fractions of the Folkestone Beds.

The grain-size is closely related to the frequency of some of the mineral species, as will be seen in the table for the Folkestone Beds. With decrease of grain-size, the zircon- and rutile-content increases and the kyanite-, staurolite- and tourmaline-content decreases. Thus in the coarse grades of the Folkestone Beds, zircon is poorly represented, while kyanite may be the dominant mineral; in the fine fractions, zircon is always the dominant mineral and kyanite is less common.

These analyses show a fairly close resemblance to those of Hayward (1932), working on the Lower Greensand of the Dorking and Leith Hill district. He found the most abundant species to be: ilmenite, leucoxene, zircon in all beds, a greater frequency of tourmaline in the Hythe Beds than in the higher beds, as occurs in East Kent. There is a general similarity in the frequencies of the other common minerals, with some important exceptions, i.e. the occurrence in the Dorking area of sphene, cassiterite and dumortierite, none of which was detected in the East Kent Lower Greensand.

(b) **The source of the Lower Greensand Beds in East Kent.** Little is known as yet of the source of any of the Lower Greensand Beds. Groves (1931) considered that the Dartmoor source did not contribute to the sediments of the Lower Greensand but Hayward (1932) gave evidence for both a Dartmoor and an Armorican source, the latter being in the ascendency.

A comparison of the frequency, varietal features and association of the East Kent detritals with those described by Brammall (1928) and Groves (1931) from south-west England, show that there are many differences. Most striking is the constant and frequent presence of staurolite and kyanite, the latter sometimes being the predominating mineral. These are derived from some area of regional metamorphism, and Armorica is the nearest known source. These two minerals are generally large, due perhaps to the fact that they have not travelled far, or to their having passed through only one cycle of sedimentation.

Among the minerals of igneous origin, the abundant ilmenite and its predominance over magnetite is a feature also of the Dartmoor detritals. On the other hand, the zircons are predominantly clear, the dusky zoned Dartmoor variety being either very rare or absent, while purple zircons—rare in Dartmoor detritals—are more common in the East Kent deposits. There are other differences: garnet is virtually absent from the Sandgate and Folkestone Beds; monazite and brookite are rare; anatase is very rare and occurs only in tabular form, and no 'steel blue' or 'olive green' varieties have been detected; attempts to identify cassiterite, an important pointer to a Dartmoor source, by chemical means produced a negative result; tourmaline does not show the colours characteristic of the Dartmoor varieties, but has a number of pleochroic colour schemes of its own. Minerals characteristic of SW. sources other than Dartmoor described by Groves are also poorly represented or absent, e.g. sphene and acicular tourmaline.

It appears, then, that the Lower Greensand beds of East Kent have more than one source. The abundant staurolites and kyanites indicate, as Hayward said, that Armorica (or some nearer source) was in the ascendency. The minerals of igneous origin differ from the Dartmoor detritals in many respects, and it is necessary to postulate another source. Hayward suggested a granite mass making up part of the London platform and now buried, but because the East Kent detritals are well rolled and small, and their percentage so very low, this seems to be an unlikely source. It seems more probable that they are derived from older sedimentary rocks and the presence of Wealden pebbles in the Folkestone Beds in this area favours a Wealden source.

ACKNOWLEDGMENTS

The author wishes to express his thanks to Professor S. W. Wooldridge for his guidance and assistance while this work was in progress, and to Professor R. L. Wain, for providing laboratory facilities at Wye College. He would also like to thank Mr. R. Casey for identifying the fossils collected, and Dr. J. F. Kirkaldy for his assistance in the preparation of this paper.

EXPLANATION OF PLATE 1

The Hythe Beds, Boughton Quarries (777.517) 45–50 ft. of rag and hassock are seen overlain by 18 ft. of thinly bedded chert and reddish loamy sand.

REFERENCES

BRAMMALL, A. 1928. Dartmoor detritals. A study in Provenance. *Proc. Geol. Assoc.*, **39,** 27.

CASEY, R. 1939. The upper part of the Lower Greensand around Folkestone. *Proc. Geol. Assoc.*, **50,** 362.

————. 1950. The junction of the Gault and Lower Greensand in East Sussex and at Folkestone. *Proc. Geol. Assoc.*, **61,** 268.

CORNES, H. W. *et alii*. 1925. The geology of the Canterbury District. *Proc. Geol. Assoc.*, **36,** 257.

————. 1928. Report of the Weald Research Committee. *Proc. Geol. Assoc.*, **39,** 227.

DE RANCE, C. E. 1868. On the Albian or Gault of Folkestone. *Geol. Mag.*, London, **5,** 163.

FITTON, W. H. 1836. Observations on some of the strata between the Chalk and the Oxford Oolite in the South East of England. *Trans. Geol. Soc. Lond.*, (2), **4,** 103.

————. 1843. Comparative remarks on the Lower Greensand of Kent and the Isle of Wight. *Proc. Geol. Soc. Lond.*, **4,** 208.

GOSSLING, F. 1929. The geology of the country around Reigate. *Proc. Geol. Assoc.*, **40,** 197.

GREGORY, J. W. 1895. On a collection of fossils from the Lower Greensand at Great Chart. *Geol. Mag.*, London (dec. 4), **2,** 97, 187.

GROVES, A. W. 1931. The unroofing of the Dartmoor Granite and the distribution of its detritus in the sediments of Southern England. *Quart. Journ. Geol. Soc. Lond.*, **87,** 62.

HAYWARD, H. A. 1932. The geology of the Lower Greensand in the Dorking–Leith Hill District, Surrey. *Proc. Geol. Assoc.*, **33,** 1.

HINDE, G. J. 1885. On beds of sponge remains in the Upper and Lower Greensand of the South of England. *Phil. Trans. Roy. Soc. Lond.*, Pt. 2, p. 403.

KIRKALDY, J. F. 1932. The geology of the country around Hascombe, Surrey. *Proc. Geol. Assoc.*, **43,** 127.

————. 1937. The overstep of the Sandgate Beds in the Eastern Weald. *Quart. Journ. Geol. Soc. Lond.*, **93,** 94.

————. 1939. The history of the Lower Cretaceous Period in Britain. *Proc. Geol. Assoc.*, **50,** 379.

PACKE, C. 1743. A new chorographical chart of East Kent.

PRICE, F. G. H. 1875. On the Lower Greensand and Gault of Folkestone. *Proc. Geol. Assoc.*, **4,** 135.

SIMMS, F. W. 1843. An account of a section of strata between the Chalk and Weald Clay in the vicinity of Hythe, Kent. *Proc. Geol. Soc. Lond.*, **4,** 206.

SMITH, W. 1819. A geological map of Kent.

SPATH, L. F. 1923–43. A monograph of the Ammonoidea of the Gault. *Monogr. Palaeontogr. Soc.*, London.

————. 1930. On some Ammonoidea from the Lower Greensand. *Ann. Mag. Nat. Hist.*, London (10), **5**, 417.

————. 1935. Field Meeting at Folkestone. *Proc. Geol. Assoc.*, **46**, p. 429.

TOPLEY, W. 1872. On the agricultural geology of the Weald. *Journ. Roy. Agric. Soc.*, (2), **8**, 241.

————. 1875. The geology of the Weald. *Mem. Geol. Surv.*

WHITTAKER, W. 1908. The water supply of Kent. *Mem. Geol. Surv.*

DISCUSSION

DR. J. F. KIRKALDY congratulated Mr. Worrall on his communication, particularly on his account of the petrology of the beds studied. Surprisingly little had been published on the detailed petrology and petrography of the Lower Greensand, so Mr. Worrall's paper, and other work now in progress in this field, were especially welcome.

The speaker enquired if the chert-bearing beds of the west of the area, regarded as of residual origin, showed any signs of disturbance by solifluxion processes.

MR. WOOD congratulated Mr. Worrall on his most interesting paper. He said he was especially interested in the heavy mineral work as he had recently been examining the Lower Greensand heavy minerals in the Western Weald.

He was pleased to be able to confirm Mr. Worrall's findings of the greater abundance of tourmaline in the Hythe Beds than in the Sandgate Beds, and was in complete agreement that this difference was due almost entirely to the coarser grade of the Hythe Beds.

With regard, however, to the Folkestone Sands, he differed. Although Mr. Worrall had made no reference to the fact, his tables showed a distinct richness of kyanite in these sands. Mr. Wood stated that he had traced this abundance of kyanite throughout the Western Weald and considered this difference in the heavy mineral suites to be of real genetic significance.

He asked Mr. Worrall if he had any evidence of authigenic activity in the heavy mineral suites.

Lastly, with regard to the derivation of the beds, Mr. Wood agreed with Mr. Worrall on his major conclusions. The Hythe and Sandgate Beds provided an extremely well-rounded suite presumably derived from sediments of Wealden, Jurassic, Carboniferous or O.R.S. age. But on consideration of the remarkable similarity of the Folkestone Sand lithology on the N. and S. outcrops of the Weald and the fact that the London Platform was soon to be submerged by the Gault Sea, Mr. Wood suggested that the landmass must have been of extremely low relief and in Folkestone Sand times at least providing little detritus to the basin of deposition. He also agreed that the Brittany landmass was by far the most probable source of the coarse kyanite and staurolite of these Folkestone Sands.

MR. B. C. WORSSAM remarked that a great part of the area included in the paper had been mapped in recent years on the six-inch scale partly by himself and partly by Mr. J. Ineson, as part of their official Geological Survey work. This work covered the whole of the Lower Greensand outcrop shown on Mr. Worrall's sketch-map between Willesborough and Harrietsham as well as the ground farther west to beyond the Medway Valley. He said that certain suggestions made by the author regarding the succession and structure of the Lower Greensand Beds over this area to the west of Willesborough appeared to be at variance with his interpretation. He wished to make the following points at this stage.

(1) The Atherfield Clay has been mapped by the speaker and his colleagues as a continuous band along the face of the Hythe Beds escarpment between the Medway and Stour Valleys, and there is clear evidence for its continuation eastwards past Ashford at least as far as Willesborough.

(2) Although it has long been known from the evidence of boreholes for water that the Hythe Beds become rapidly thinner, and probably die out altogether a short distance northward from their outcrop, the author appears to offer no fresh explanation of the fact. Mapping near Ashford has shown that the Hythe Beds, which consist of alternate rag and hassock layers, diminish in thickness from approximately 50 ft. in the Great Chart outlier to 20 ft. or less along the main outcrop a mile or two to the north-east. This thinning was clearly seen, for instance, in 1951 in a deep drainage trench which crossed the outcrop of the Hythe Beds, near Repton Manor, about ¾ mile NW. of the centre of Ashford, where, with a thickness of about 15 ft. and width of outcrop of little more than 100 yds., the Hythe Beds give rise to a locally steepened bank rather than an escarpment, capped by Sandgate Beds. The Atherfield Clay was also exposed in the trench. These rag and hassock beds, near Ashford, possess a more littoral facies than those exposed in quarries near Great Chart, and it is suggested that the present feather-edge of the Hythe Beds in fact approximates to the north-eastward margin of the trough in which they were deposited.

(3) The beds at the junction of the Sandgate and Hythe Beds, though exposed in numerous quarries in the Maidstone and Ashford districts, are rarely seen in a fresh condition, the Hythe Beds often being decalcified by sub-aerial weathering to some depth, in places beneath a cover of up to 10 ft. of Sandgate Beds—a fact pointed out by the author. There seemed to the speaker to be no evidence, however, that any of this weathering is other than of Pleistocene or Recent age.

Mr. Worssam, in concluding his remarks, referred to the strike-fault postulated by the author to account for the presence of the outliers of Hythe Beds south of Mersham. Mapping of the ground farther west had produced no evidence for the continuation of any such fault separating the outlier at Great Chart from the main outcrop.

MR. E. E. S. BROWN congratulated the author on his detailed study of an area of Lower Greensand and particularly on the use of an auger. He considered that the ragstone of the Hythe Beds should not be regarded as a facies because there was indubitable evidence that it was of secondary formation and subject to subsequent solution—which might account for its absence north of the outcrop. He queried the difficulty in distinguishing between Atherfield and Weald Clays because, in areas west of Maidstone, they can be determined by examination of the lithology by methods developed by the late Mr. F. Gossling. He asked whether the outliers of Hythe Beds could be the remains of masses which had slipped at a time when the main outcrop had extended farther to the south-west.

MR. WORRALL, in his reply, thanked the members for the interest they had shown in his paper.

In reply to Dr. Kirkaldy, he said that the chert beds did show some contortion. This is well seen in the Boughton quarry where the corrugated layers of chert occur over almost horizontally bedded ragstone.

He was gratified to hear from Mr. Wood that the results of his mineralogical studies in the Western Weald bore so close a resemblance to his own. He thanked him for pointing out that kyanite in his tables was more abundant in the Folkestone Beds than in the lower beds, an overlooked fact which was borne out on examining the individual results of the separations. He had seen no certain evidence of authigenic minerals. With regard to the derivation of the beds, he thought that the minerals of igneous origin were too small, too infrequent, and contained too few of the more unstable but commoner rock-forming minerals in all the beds, to have come direct from an igneous source.

While he appreciated Mr. Worssam's detailed field work in the west of the area, he would like to repeat that in many places he had found nothing but Weald Clay immediately beneath the Hythe Beds. In view of the variety of lithology ascribed to the Atherfield Clay, it would be interesting to know what Mr. Worssam had mapped, and on what criteria he could tell it was Atherfield Clay. With regard to his second point, mechanical analyses has not shown any difference of calcium carbonate content or any increase of the coarse sand of the non-calcareous fraction, if that was what was meant by a 'more littoral facies', and the author could not agree that there was any good evidence of a shoreline immediately to the north of the area. He queried the statement that the junction of the Hythe and Sandgate Beds was to be seen in 'numerous quarries' in the area, but agreed that his suggestion of intraformational weathering of the Hythe Beds was open to objection.

In reply to Mr. Brown, he agreed that the formation of the ragstone bands was a subsequent formation, since mechanical analyses showed that the rag and hassock differed only in the proportion of calcium carbonate they contain and were evidently laid down as a uniform deposit. Mechanical and mineralogical analyses of bore-hole samples to the north of the outcrop might confirm or disprove his suggestion of decalcification since the non-calcareous fraction of the Hythe Beds was quite different from the Sandgate Beds. He had not attempted Gossling's method of distinguishing the Atherfield Clay from the Weald Clay, as he was assured by handling and appearance that what he had seen in most cases was Weald Clay. He had considered the possibility of an extensive landslip to account for the outliers to the south of the main outcrop, but regarded their disposition and dip too regular for this explanation.

The Moine Thrust—its discovery, age, and tectonic significance

by DONALD B. McINTYRE
University of Edinburgh

Received 17 August 1953; read 2 July 1954

CONTENTS

1. INTRODUCTION ... page 203
2. THE DISCOVERY ... 204
3. RELATIONSHIP BETWEEN THE MOINE THRUST AND THE FOLDING OF THE MOINE SCHISTS ... 208
4. AGE ... 212
    (a) The Old Survey Argument ... 212
    (b) The New Survey Argument ... 212
    (c) Gilbert Wilson's Argument ... 214
5. CONCLUSIONS ... 216
EXPLANATION OF FIGURE ... 217
REFERENCES ... 217
APPENDIX ... 219
DISCUSSION... 220

ABSTRACT: The history of the discovery of the Moine Thrust is reviewed and the origins are traced of the erroneous correlation of folding and thrusting in the Highlands. The reasons for believing that the folds and thrusts represent two successive tectonic events, which were separated by an unknown but probably considerable time-interval, are summarised. The evidence for the age of the Thrust is examined and some new data bearing on the problem are presented.

---

1. INTRODUCTION

THE MOINE THRUST is the greatest of a series of powerful dislocations affecting the rocks of the North-west Highlands of Scotland. On it the Moine Schists of the Northern Highlands have moved in an approximately north-westward direction for a distance known to exceed ten miles, so that these highly folded and regionally metamorphosed rocks now rest on top of the Lewisian, Torridonian and Cambrian rocks of the foreland. Lesser thrusts lie below the Moine Thrust and, except where they have been cut out by it, outcrop further west; on these thrust-planes, slices of the foreland have been driven north-westwards.

Much has been written about the Moine Thrust, and its outcrop has long been a place of geological pilgrimage. It may therefore appear unnecessary to add to the already voluminous literature; indeed Professor Read has recently said ‘it would be well to forget about the Moine Thrust for ten years and then the Highlands could be dealt with in a proper manner’ (1951, p. 17), and he congratulated the writer for striving to do this.

It is becoming increasingly clear that the Moine Thrust has been given a position of unwarranted dominance in Highland geology; it seems appropriate to pause and consider its tectonic significance in the light of our present knowledge, for a new phase of Highland research has begun. The writer feels that, in reviewing the evidence at this time, he is following the spirit of Professor Read's counsel.

2. THE DISCOVERY

The superposition of gneiss on limestone and quartzite in the Eriboll district was recorded by Macculloch (1819, **2,** pp. 510–511; **3,** pl. 32, fig. 1). The earliest interpretation of the phenomenon was published in 1839 by R. J. H. Cunningham. Although conscious that nowhere else had sedimentary rocks been found underlying gneiss, and aware that earth-movements can make 'the oldest strata appear the highest in the order of sequence', he felt compelled by the field evidence to draw the following conclusion: 'in Sutherland there are two systems of crystalline rocks, one being older than conglomerate [Torridonian], quartz-rock, and limestone [Cambrian]; and another which has been formed subsequently to all. There is found a gneiss newer than a quartz-rock, which has resulted from the breaking up of a still older formation; and as organised fossils have been discovered in the oldest known mechanically formed strata, there is also some cause to believe that there are gneisses and mica-slates [Moine] that have been elaborated after these were called into being' (1839, p. 28). It is significant that Murchison marked his copy of Cunningham's monograph with thirteen lines in the margin opposite this passage.

In 1854, C. W. Peach was sent from the custom-house at Wick to visit a wreck on the north coast, and while at Durness he found Lower Palaeozoic fossils in the limestone. The tremendous significance of this discovery was immediately appreciated by Murchison who had worked in the area with Sedgwick more than a quarter of a century before. Murchison had no difficulty in persuading his friend James Nicol to accompany him to Sutherland the following summer. Nicol was so impressed with the evidence that he returned in 1856. He confirmed (1857) that, in Eriboll and near Ullapool, metamorphic rocks overlie the fossiliferous limestone. The age of the latter (now known to be Cambrian) he thought might be Carboniferous, but he pointed out that the chief objection to this was the fact that the limestone dips under the gneiss, which, in turn, underlies the Old Red Sandstone. He was careful, however, to emphasise that further investigation was required to decide whether the overlying gneiss had been metamorphosed *in situ* or had been pushed up over the quartzite and limestone (p. 35). He concluded: 'Whether we consider the gneiss resting on the latter [quartzite and limestone] as a newer metamorphic group, or merely as a portion of the lower gneiss forced up over it in some great convulsion, we have still views of very great interest opened up to us in the history of these Highland mountains' (p. 36).

By 1858 Murchison (1859) had definitely concluded that there was an upward stratigraphical sequence eastwards from Lewisian, through what we now call Torridonian and Cambrian, to the schists of the A'Mhoine peninsula. Moreover, he maintained that the passage from the Cambrian to the Moine was not only upward but conformable. This view was put forward in the autumn of 1859 at the British Association Meeting at Aberdeen, and Nicol, who held the Chair of Geology at Aberdeen University, dissented. Thereafter the disagreement was permanent between Murchison and his 'fellow-labourer', Nicol, of whom he testified that 'no man is more impressed with the desire to ascertain the whole truth'. The following year Murchison (1860) published a supplement to his previous paper, and expressed definite disagreement with Nicol's dislocations; he was supported by Ramsay and Harkness.

In 1861, Nicol (1861) emphasised the diversity of rocks in contact with the Moine Schists and maintained that this disproved the postulated conformable succession. He did not believe that metamorphic rocks like the Moine Schists could have formed *in situ* above unmetamorphosed sediments, and pointed out that Murchison had accepted the existence of overthrusts in the Alps. There were two serious errors in Nicol's paper: viz. (i) that many of the gneissose rocks were igneous eruptives, and (ii) that the Cambrian rocks always overlie or abut against, but never dip under the Moine Schists (*op. cit.*, p. 113). There is no doubt that the latter error, which is contrary to his earlier and more nearly correct observations, prejudiced many against his views. This was particularly unfortunate since, during the same year, a paper by Murchison and Geikie (1861) was published, which, supported as it was by the further authority of Ramsay and Harkness, temporarily closed the controversy with the apparent defeat of Nicol. Murchison's victorious position is summarised in the 4th Edition of *Siluria* (1867, pp. 166–171).

The controversy was re-opened in 1878 with the publication of Hicks' investigation of the Loch Maree area. In this he agreed (as he put it in 1897) more with Nicol than with 'Murchison and the Survey'. An unfortunate aspect of the dispute was that three successive Director-Generals of the Geological Survey (Murchison, who died in 1871, Ramsay and Geikie) supported the conformability and the contest became the Survey versus the Rest. Thus in the discussion following Hicks' paper, Ramsay defended his late chief's views. Nicol died in 1879, only five years before the universal acceptance of his overthrust.

The year 1883 was one of great progress in the geology of the North-west Highlands. Lapworth, who had begun work there in 1882, took

Teall and Blake over Durness and Eriboll and convinced them of the reality of the thrusts; indeed, he was taken seriously ill in Eriboll and with the excitement of discovery, his vivid imagination made him believe that the movements had not yet ceased. Only the first part of his *Secret of the Highlands* was published (1883); in it he employed the concept of overfolds passing into overthrusts, and acknowledged the inspiration of Heim's *Mechanismus der Gebirgsbildung*.

In the same year Callaway (1883 *a* and *b*) announced that his work in Durness and Assynt had led him to the conclusion that the Moine Schists had been brought over the Cambrian by a powerful lateral thrust from the east, and he called attention to examples of comparable inversions in the Alps cited in Geikie's text-book. In the discussion at the Geological Society, Hicks expressed his surprise that no one had risen to defend the views maintained by the Geological Survey. He must have been ignorant that Geikie, who had succeeded Ramsay in 1882, had already put into operation a masterly plan designed to bring the controversy to an end.

In his Report for the year 1883, Geikie wrote (1884*a*): 'As the true key to the Geological structure of the Highlands is not to be found in any of the areas now in the course of examination by the Survey, but along the western borders of the Counties of Sutherland and Ross, of which the Ordnance maps are now available, and as it is of great importance to have the base lines of the Survey-work accurately determined, I resolved to begin the survey of the extreme North-west Highlands during the early part of the Summer' [1883]. 'Accordingly', as he wrote in his autobiography (1924, p. 214), 'in the spring of 1884 [*sic.* 1883] I selected B. N. Peach and John Horne as the officers to whom this important, and probably difficult, task could be most confidently assigned. They were instructed to get at the truth, regardless of anything that had been published on the subject.'

During their first season (1883) in the North-west Highlands they mapped the Durness area on the six-inch scale. In the summer of 1884, armed with the knowledge of the detailed stratigraphy of Durness, the party extended the mapping eastwards to Eriboll. North of the peninsula of Heilim, on the eastern side of Loch Eriboll, Peach discovered what is now the classic locality for schuppen structure: 'The real meaning of the whole series of phenomena broke upon him like a vision. Whereupon, as on all such occasions, his mind took a mighty bound forward, and rapidly left all others behind in depth of insight into the new principles which he himself had but for a day or two discerned' (Greenly, 1927, p. 5).

It cannot have been easy for Geikie to admit the error of Murchison, 'the greatest benefactor and one of the warmest friends I ever had'. His own account of the crisis is interesting: 'by the end of the summer [1884] these careful observers had advanced so far as to be convinced that Murchison's interpretation of the structure of the ground could not be maintained. I had implicitly accepted that interpretation, and had shared in Murchison's attempt to apply it to the rest of the Highlands. Naturally I could not bring myself to abandon it until I had seen with my own eyes such evidence as would convince me of its error. Accordingly I made for the extreme north-west of Scotland before the middle of October, and joined my colleagues at Durness' (1924, p. 214). 'With every desire to follow the interpretation of my late chief, I criticised minutely each detail of the work upon the ground; but I found the evidence altogether overwhelming against the upward succession which Murchison believed to exist in Eriboll from the base of the Silurian strata into an upper conformable series of schists and gneisses' (Geikie, 1884*b*). 'I arranged that Messrs. Peach and Horne should prepare and send up to London a conjoint report, giving succinctly the results of their investigation, with the neccessary illustrative diagrams. To this report I wrote a preface with a frank confession that I had been mistaken, and that I entirely accepted the opinion of my colleagues. These documents appeared in *Nature* of 13th November 1884. They mark a noteworthy incident in the history of Scottish geology' (Geikie, 1924, p. 215).

Geikie not only immediately made public his acceptance of 'the conclusions to which the surveyors, step by step and almost against their will, had been driven', but was quick to acknowledge that others had seen the truth before him; 'It would require more space than can be given in these pages to do justice to the views of those geologists, from Nicol downward, by whom Murchison's sections have been criticised, and to show how far the conclusions to which the Geological Survey has been led, have been anticipated' (Geikie, 1884*b*).

The part played by Geikie has often been unfairly criticised. In the joint paper of 1861, which temporarily closed the controversy, he had been requested to accompany his chief who was forty-four years his senior. He took no further part in the controversy until he became Director-General of the Survey, and then only a year passed before 'the whole force of the Geological Survey of Scotland laid siege to the Highland fortress' (as Blake put it in 1884). The report in *Nature* appeared less than three years after he had succeeded Ramsay; it is difficult to see how he could have achieved the result more swiftly. It was Geikie who introduced the term *thrust-plane* into the literature, and likewise the estimate of a ten mile minimum for the displacement (based on the Fair Aird klippe).

Lapworth's generous essay 'On the Close of the Highland Controversy' appeared in 1885; 'The old subject of dispute has utterly disappeared, and there is no longer any reasonable excuse for dissension. We have all been partly right and partly wrong. It is a time for a hearty laugh all round, a time to shake hands and be friends'.

By 1888 the surveyors were persuaded (Geikie, 1888, p. 412) that the overthrusts were not necessarily preceded by over-folds, and the same year saw the publication of Cadell's experimental production of thrust-structures. In 1891 *Olenellus* was found in the Fucoid Beds and so gave, at last, a definite age-marker in the North-west Highlands. By 1896 the entire outcrop of the thrust had been mapped from Loch Eriboll to Skye. The classic Memoir on the Geological Structure of the North-west Highlands of Scotland was published in 1907 (Geikie, 1907). Fittingly it was edited by Geikie, although he had retired from the Survey in 1901. Its publication marked the end of an heroic era.

3. RELATIONSHIP BETWEEN THE MOINE THRUST AND THE FOLDING OF THE MOINE SCHISTS

'Ever since the discovery of Silurian fossils in the rocks of North-west Sutherland, it has been recognised that in that region lies the key to the structure of the Scottish Highlands' (Geikie, 1884*b*). 'The importance of the discovery of this belt of extreme complication [the Moine Thrust] in the North-west Highlands can hardly be overestimated. It gives us the key to the geological structure, not only of the Highlands, but of all the areas of younger crystalline schists in our own area, and will doubtless be found to explain much in the geological structure of Scandinavia' (Geikie, 1889, p. 13).

The Moine Schists were first approached, both by Lapworth and by Peach and Horne, from the west across the schuppen and crush zones which have such wide outcrops to the east of Loch Eriboll. Lapworth in particular had been quick to realise the significance of the rocks for which he coined the term 'mylonite' (1885*a*): 'The variegated schists which form the transitional zones between the Arnaboll gneiss [thrust Lewisian] and Sutherland mica-schists [Moine] are all essentially mylonites in origin and structure, and appear to have been formed along many dislocation planes, some of which still show between them patches of recognisable Archaean and Palaeozoic rocks.' When Geikie sent Peach and Horne to Durness in 1883 with instructions to work eastwards towards the Kyle of Tongue, he believed that the traverse would enable the stratigraphical 'base-line' of the Moine Schists to be established. The result, however, was that the surveyors arrived at A'Mhoine full of enthusiasm for the concept of thrusting and were awed at the magnitude of the dynamic forces which had operated in the North-west Highlands.

It is therefore hardly surprising that the Moine Schists were taken as the end-products of the metamorphism which had accompanied the thrusting. According to Lapworth (1884, p. 438), the flaggy schists of A'Mhoine were thoroughly recrystallised mylonites: 'I hold that the Sutherland Schistose Series is composed of a complete intermixture of Archaean and Assynt [Cambrian] rocks, the two series being so interfolded and interfelted together that (exception being made of those zones near the great overfaults where the metamorphism is incomplete) they can never be separated in the field, but must be mapped simply as "metamorphic".' 'The Eastern Gneissic Series [Moine] has thus no pretension whatever to the title of a sedimentary rock-system. It is a petrological rock-massif, a metamorphic compound, composed of local elements of very different geological ages. In all their essentials these views appear to agree with the far more extended and minute results worked out independently by Messrs. Peach and Horne in 1884, and published during the same year' (1885*a*).

In 1888, Geikie wrote: 'The eastern metamorphic series of Sutherland and Ross not only contains Archaean rocks, but also local patches of metamorphosed Palaeozoic, intrusive, and segregatory rocks, together with local patches of material, probably compounded of all these in different degrees. The eastern metamorphic series has received its present strike, pseudo-bedding, and its present foliated and mineralogical characteristics through the agency of the crust-movements which have operated within the district since Lower Silurian [Cambrian] times' (p. 386). 'It is obvious that the facts now brought forward furnish a large amount of evidence in support of the theory *that regional metamorphism is due to the dynamical and chemical effects of mechanical movement acting alike on crystalline and clastic rocks*' (p. 438).

In 1892 Peach re-discovered evidence (cf. Macculloch, 1819, **2**, p. 94) near Loch Carron that the Torridonian had been converted into 'granulitic flagstones, like the so-called "Moine-schists"'. The following year Geikie and Teall examined the evidence in the field, and in his Report for that year Geikie wrote: 'There is every reason to anticipate that the Torridonian series has largely contributed to the formation of the eastern or younger schists' (Geikie, 1894, p. 264). Geikie insisted that the mapping of the thrust-zone should be completed from Loch Eriboll to Skye, and so, when studying the Moine Schists, the surveyors were kept aware of the existence of the Moine Thrust and reminded of the scale of its movement. The dynamic origin of the Moine Schists thus continued to find favour. In 1899 Geikie recorded the following views: 'Probably various groups of rock have been crushed and metamorphosed to make up these schists. As the mapping has advanced southwards, evidence has increased that much of the Moine Schists consists of material that was laid down as sediment. Probably the Torridon sandstone was largely drawn upon in the process of the manufacture of these schists, and there may also have been Cambrian or even later sediment, which underwent the same conversion into a foliated crystalline condition' (1899, p. 23). This implies a post-Cambrian age for the folding and metamorphism.

That there was probably a close connection between the Moine Thrust and the folding of the Moine Schists was first clearly stated by Geikie in

1884: 'The persistent parallelism of the faults and of the prevailing north easterly strike of the rocks indicates that the faulting and tilting were parts of one continuous process. The same dominant north easterly strike extends across the whole Highlands, and also over the Silurian tracts of Southern Scotland and the north of England. There is reason to regard it in all these regions as probably due to one great series of terrestrial movements.' Peach's section across the Highlands, published posthumously nearly fifty years later (1930, fig. 27), expresses exactly the same view of the structural history of the Highlands.

Horne, however, did not agree with Peach's view that the metamorphism and folding of the Schists was post-Cambrian and connected with the thrusting (see Geikie, 1899, p. 15). He (Peach & Horne, 1930, pp. 200–1) contrasted the lithology of the Torridonian with that of the Moine, and concluded that the latter consisted mainly of sedimentary schists of pre-Torridonian age, which, near the thrusts, had been modified by the post-Cambrian movements. Barrow, who in 1885 visited Sutherland under the guidance of Peach and Horne, appears to have been the first to recognise that, in the vicinity of the thrusts, the old crystalline structure of the Schists had been broken down by later movements (Green, 1935, p. lxvi).

Criticism of the hypothesis of a close connection between folding and thrusting was made on tectonic grounds by F. E. Suess at the 1929 Meeting of the British Association. Impressed by Bailey's suggested continuation of the Moine Thrust through Islay, Suess wrote: 'It crosses obliquely the different zones of the Caledonian dynamic unit; therefore it must be younger than the Caledonian movement, and, in my opinion, the great thrust has no immediate relation to the Caledonian structure proper. . . . It is independent of and younger than the Caledonian mountain building. By no means can it be considered a symmetrical equivalent of the south-easterly Dalradian movement in Scotland and in Scandinavia' (Suess, 1931, pp. 79–80). Recent attempts to reconstruct the form of the major structures in Attadale (McIntyre, 1952) and Fannich (Rutledge, 1952) have not only shown that some of the major overfolds, which were supposed to trend NE.–SW. and be overturned to the north-west, do not exist, but make it highly likely that the structures are cut off obliquely by the Moine Thrust.

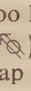
The first Highland geologist 'to release himself from the baleful influence of the Moine Thrust' and give a systematic discussion of the relevant evidence was H. H. Read (1934). Two main lines of argument led him to conclude that there was a substantial difference in age between the folding and the thrusting:

(i) He had previously correlated, on petrographic grounds (1931, pp. 178–9), the Ben Loyal syenite, which is later than the folding and regional metamorphism of the Moine Schists, with the Loch Ailsh and Loch Borolan alkaline rocks, which are earlier than the thrusting.

(ii) 'The dislocation-metamorphism is undoubtedly superposed upon the general Moine metamorphism. . . . I am of the opinion that the general metamorphism and the dislocation-metamorphism are two separate events in the history of the Moine Series. . . . The dislocation-metamorphism arises from the post-Cambrian movements that are of late Caledonian age' (1934, pp. 307–8).

Read's view was supported in a recent discussion (Wilson, 1953, pp. 148, 150) when Dr. Gilbert Wilson and the present writer emphasised 'the striking difference in style between the folded schists and the mylonites', and claimed that 'the time-relationship between the folding of the Moines and the movement on the Moine Thrust was indisputable; the folds were not only dead but cold when the thrusting took place'.

It is unfortunate that linear structures, which can be of such value in tectonic analysis, were, by a combination of circumstances, misinterpreted by some of the early workers in the Highlands.[1] As a result, progress in understanding the tectonic history of the Highlands was considerably retarded. From 1884, when the existence of the Moine Thrust was officially recognised, the surveyors recorded *a*-lineations of various types in the mylonite zone; these trend WNW.–ESE. parallel to the direction of movement of the Moine Thrust. It is, of course, a mere coincidence that these lineations are approximately parallel to a widespread *B*-lineation of pre-Torridonian age in the Lewisian of the foreland; the south-east trending *B*-lineation, which is so prevalent in the Moine Schists is probably equally unrelated to the thrusting (Phillips, 1949; Wilson, 1953). The Moine Schists were once thought to be recrystallised mylonites, and so the mullion and rodding structures in them were considered to be caused by the thrust-movements.

In his description of the Cowal district of the South-west Highlands, Clough (1897) recognised that the folds trend NE.–SW. and described and mapped lineations approximately normal to this direction. These observations naturally seemed to be in agreement with the hypothesis that folds and thrusts were syngenetic. In 1895, Hinxman's map of the Tomintoul area (Sheet 75) was published; he too had mapped widespread NW.–SE. trending lineation, and the symbol () he used to represent it is the same as that employed on the one-inch map of Eriboll (Sheet 114) published in 1889. The symbol used by Clough has a significant difference; it has no barb to indicate sense of movement or plunge. Hinxman's arrow is directed up-plunge apparently solely on the basis of a supposed connection with the Moine Thrust (see McIntyre, 1950, p. 332; 1951*a*, p. 11). Like the linear structures shown to the east of the Moine Thrust on the Eriboll Sheet, Hinxman's lineation is parallel to the fold-axis. Clough, on the other hand, recorded a relatively inconspicuous *a*-lineation (see McIntyre, 1953*b*); as the rocks show intense megascopic folding, the plunge is too variable to be mapped, but, since the plunge of the fold-axis is low, it is possible to map the trend of the lineation.

---

[1] See, however, 'Lugeon's unpublished interpretation of the Strath Oykell Mullions', *Geol. Mag.*, London, 1954, 91, p. 174.

F. C. Phillips brought forward petrofabric evidence indicating that 'the Moine schists were brought to their present state of regional metamorphism by a deformation acting along approximately south-west and north-east lines . . . prior to the dislocation phase of the Caledonian movements' (1937, p. 603). This conclusion has been supported by recent work on diverse lines by McLachlan (1953), McIntyre (1950; 1951*a*, *b*), McIntyre & Turner (1953), Phillips (1949; 1951), Wilson (1952; 1953), and others.

The plastic style and complex pattern of the schists (McIntyre, 1951*c*) contrast with the brittle style and apparently simple pattern of the thrusts. It may ultimately be possible to correlate the folds and thrusts in a single movement-picture, but with our present knowledge we must assume that they constitute two separate tectonic events which were separated by an interval of time of unknown length.

4. AGE

The lower age-limit of the thrust is determined by the age of the youngest rocks affected. The Durness Limestone is Cambrian probably ranging into the Ordovician. The alkaline complexes of Loch Borolan and Loch Ailsh cut the limestones and are sheared by the movements, and certain lamprophyric dykes with a 'distinct resemblance to the Lower Old Red Sandstone intrusions of Central Scotland' (Phemister, 1948, p. 48) are foliated in the thrust-zone.

In attempts to define the upper age-limit, three groups of arguments have been used:

(a) **The Old Survey Argument.** Geikie (1884*b*) claimed that the thrusting was earlier than 'that portion of the Old Red Sandstone period represented by the breccias and conglomerates of the Highlands', since these are 'largely composed of the crystalline schists' (1889, p. 18). This is the argument used in the 1907 Memoir (Geikie, 1907, p. 473) and in Peach & Horne (1930, p. 118); it is based on the assumption that the folds and the thrusts are of the same age. The present writer agrees with Read's statement (1934, p. 308): 'If it cannot be shown that the general metamorphism and the dislocation-metamorphism are not both of Caledonian age, it certainly cannot be shown that they are both of this age.'

(b) **The New Survey Argument.** In the Northern Highlands Regional Guide (Phemister, 1948, p. 51) no reference is made to the old argument; instead two new lines of evidence are put forward:

(i) The movements 'are older than certain lamprophyric sheets which belong to the "Newer Granite" suite of intrusions and are found emplaced along thrust-planes'.

In a recent discussion the present writer quoted this statement and commented: 'This is an argument which was not used in the North-West Highlands Memoir, and the speaker said he did not know of any intrusion of undoubted "Old Red" age which is demonstrably younger than the thrusts; if any such intrusions does indeed exist, it should be carefully re-examined to test its validity as an age-marker' (1953*a*, p. 148). On the Eriboll Sheet (114), published in 1889, a basic dyke is shown to cut a schuppen of Lewisian, a thrust plane, and the mylonites associated with the Moine Thrust. The locality is nearly four miles south of Whiten Head, and about six miles WNW. of Tongue. On the Quarter Inch Sheet 5, published in 1934, the dyke is represented as cutting only the mylonites. No Sheet Memoir has been published and the dyke is not mentioned in the 1907 Memoir (Geikie, 1907).

As this dyke appeared to be the only intrusion known to cut the mylonites it was felt that re-examination of the field evidence was required, and this has now been done by the writer in collaboration with W. L. Brown, W. J. Clarke and D. H. Mackenzie. Our map (Fig. 1, inset) differs in a number of respects from the published sheet. The western half of the mylonite belt shown on Sheet 114 is, in this area, clearly derived from Lewisian-like gneisses; the quartzite outcrops along the bed of the river where a thrust-mass of Lewisian has previously been mapped. Two schuppen of Lewisian-like rocks are enclosed in the quartzite near its eastern limit. Above the eastern bank of the Allt nan Earbagan, where the stream flows nearly due north, the gneisses are much mylonitised, and 'frilled schist' is developed on the shear zones. These are presumably the mylonites of the Arnaboll Thrust.

The outcrops of the dyke are confined to the area of mylonitised Lewisian-like gneiss, in and close to the Allt Airidh nan Laraich. The dyke does not outcrop in the Allt nan Earbagan and there are no exposures on the slope to the west of that stream. It forms a prominent feature in the first waterfall in the Allt Airidh nan Laraich above its junction with the main stream; the dyke is exposed over its entire width of nearly six feet. The centre is a coarse-grained biotite-fourchite; towards the margin it is a biotite-monchiquite streaked with fine-grained fourchite in which the long augite crystals, as seen in section, are aligned by flow. Idiomorphic olivine pseudomorphs are abundant in sections of several specimens from the actual contact against the mylonite. There is no doubt that the dyke is entirely later than the thrust movements.

A number of outcrops of the dyke were found further upstream. It is highly irregular and branched; at two localities it was found to be 18 in.

in width. Apart from the outcrop of biotite-fourchite mentioned above, the rock is a typical monchiquite, free from felspar, and with typical development of druses filled with analcite, calcite, biotite and sphene; no nepheline has been detected. A number of other dykes were collected for comparison. The minor intrusions mapped on the west side of the Kyle of Tongue are entirely different. At Toftcarl, three miles south of Wick in Caithness, we found loose blocks of hornblende-monchiquite with only a small amount of felspar. Our specimens from the very poor exposure at Reaster, ten miles north-west of Wick, resemble parts of the Allt Airidh nan Laraich dyke; the rock is an augite-rich monchiquite with occasional patches rich in brown biotite.

The petrographic similarity of the dyke to the monchiquites of Orkney (Flett, 1935, pp. 180–6) and Caithness (Flett, 1914, pp. 115–17) make it likely that it belongs to the Orkney–Caithness province, and is thus later than part of the Upper Old Red Sandstone. The age of these dykes has been discussed at length, but it is now generally considered that they are probably Permian (Urry & Holmes, 1941; Richey, 1939, pp. 416–19). This would exclude a Tertiary age for the Moine Thrust.

(ii) 'Pebbles of rocks sheared by the movements are found in Middle Old Red Sandstone conglomerate.'

This assertion seems to be based on Peach & Horne's description (1914, p. 79) of the boulders in the conglomerate of Eilean Iosal, near the mouth of the Kyle of Tongue. It is interesting to notice that this argument was never used by Peach & Horne, although their *Chapters on the Geology of Scotland* appeared sixteen years after publication of the Caithness Memoir. The present writer, with the collaboration of W. L. Brown, W. J. Clarke and D. H. Mackenzie (1954), has re-examined the conglomerate on Eilean Iosal and the neighbouring islands. A special search was made for boulders of mylonite but none was found. In order to estimate the proportions of the various rocks present, counts were made of all pebbles to the limit of unaided vision in two-foot squares at a number of localities. Altogether fifteen counts were made giving a total of over 5500 pebbles. The localities are distributed to cover as far as possible the visible stratigraphical range and all three islands. The content of the conglomerate is remarkably uniform.

Peach and Horne stated that, at the north-west corner of Eilean Iosal, 5 per cent of the pebbles were 'mylonised rocks' of the Moine Series. It seems likely that these pebbles showed mullion-structure and were not mylonites. The count was almost certainly made prior to the publication of Sheet 114 in 1889, and it was then assumed that linear structures in the Schists were caused by the thrust-movements.

(c) **Gilbert Wilson's Argument.** In a recent discussion Dr. Wilson (1953) advanced two further lines of evidence:

(i) 'At present Read's (1934) correlation of the post-Cambrian intrusions of Loch Borrolan, etc., with the Ben Loyal mass ties down the upper age of the movements, because fragments of the Ben Loyal syenite occur in the post-Moinian conglomeratic outliers near Tongue. Unless it can be proved that these outliers have an age other than Old Red Sandstone it seems unlikely that the Moine Thrust was not Caledonian'.

Further work is required to determine whether boulders of Ben Loyal syenite do in fact occur in the conglomerates referred to (see McIntyre, Brown, Clarke & Mackenzie, 1954), but the reasoning is in any case fallacious. All that could be concluded from Dr. Wilson's premises is that the Moine Thrust must be *younger* than certain intrusions which are older than Middle Old Red Sandstone.

(ii) 'If, as is believed, the continuation of the Thrust passes southwards between the Lewisian–Torridonian complex of Iona and the Moinian rocks of the Ross of Mull and Gribun, its age must antedate the emplacement of the Ross of Mull granite.'

This argument was first advanced by Bailey (1925, p. 45) after the discovery, independently by Anderson and Jehu, that the Iona rocks had suffered thermal metamorphism. Clough's suggestion (1911, p. 77) that the Moine Thrust might pass to the east of Iona was based on the difference in degree of metamorphism, between the supposed Torridonian of Iona and the Moine of the Ross of Mull, to the east of the granite. Jehu (1922, p. 170) has pointed out that this suggestion 'is simply an expression of the view that the two Series are not contemporaneous. From an examination of the trend of the outcrop of the Moine Thrust in the south-east of Skye, it is just as likely that the thrust passes to the west of Iona, and that the rocks of the island do not belong to the unmoved foreland of the Pre-Cambrian Series. In this connection the intensely mylonised condition of the orthogneiss of Eilean Chalbha, north-west of Iona, suggests an approach to some important thrust-plane in that direction.' It is interesting to recall that Geikie (1889, pp. 7, 16) maintained that the sedimentary rocks of Iona were part of the so-called Younger Schists of the Highlands, and lay far to the east of the Moine Thrust.

Like the Moine Schists of the Ross of Mull, the supposed Torridonian rocks of Iona are intensely folded, and the axial planes of both groups have the same general strike and inclination (Jehu, 1922, p. 170). The Colonsay flags, which are probably comparable with the so-called Upper (Flaggy) Torridonian of Iona, were reported by Wright and Bailey (1911, p. 14) to resemble the banded semi-siliceous granulites of the Moine 'in all save metamorphism'. It is therefore by no means certain that the Moine Thrust passes to the east of Iona, or that it is older than the Ross of Mull granite.

The Iona and Ross of Mull data formerly seemed to provide incidental support for a proved and accepted theory. As the main arguments have failed, the circumstantial evidence now stands alone.

5. CONCLUSIONS

The unusual character and magnitude of the Moine Thrust not only delayed the discovery of its nature, but, once its existence as a powerful overthrust had been universally admitted, caused its importance to be exaggerated. The scale, particularly at Eriboll, on which Lewisian and Cambrian rocks had been converted into mylonite, so impressed the pioneers that they were led to the belief that the Moine Schists, to the east, were the end products of the process. Generalised strike was confused with axial trend, and *B*-structure in the Schists were not distinguished from the *a*-lineations in the mylonites. These misunderstandings strengthened the view that the thrust was the contact between the foreland and the breaking folds.

It is now known that there is no intimate genetic connection between folds and thrusts. Not only is the Moine Thrust oblique to the folds, but the plastic style of deformation characteristic of the folded schists is in striking contrast with the brittle style found near the thrusts where the Schists are broken down into mylonite. The tectonics of the mylonite-zone have never been adequately described, but an investigation which promises to fill this gap has now begun. As both *a*- and *B*-structures are present in the mylonites (McIntyre, 1953*b*) the study should be of considerable interest.

The remarkable fact that the thrust-masses of gneiss and schist are much more intensely mylonitised than are the underlying Cambrian limestones and shales, suggests that the mylonites were not produced at the level where we now see them; very likely the fractures originated in depth where shearing of brittle rock against brittle rock produced mylonite which lubricated the base of the moving nappe and was carried forward with it. At the present outcrop we see not a *traineau écraseur* but a *traineau écrasé*.

Lapworth originally believed that the Thrust represented the reversed limb of an overfold, but the Survey were not long in discovering that the thrusts had not been preceded by folds; unfortunately the significance of that early realisation was overlooked. The Moine Thrust now appears to be much more closely comparable to the great zone of flinty-crush rock in the Outer Hebrides than was formerly realised; the present outcrop of the latter probably represents a deeper tectonic level than that exposed at the outcrop of the Moine Thrust, for, in the Outer Hebrides, the brittle rocks are in contact with one another. Both dislocations affected a kratogenic region. It is tempting to speculate whether they are related to the Great Glen and Highland Boundary Faults, the other two major dislocations affecting the Highland Schists.

The Moine Thrust is younger than certain dykes which have been correlated with the Lower Old Red Sandstone suite. Circumstantial evidence suggests that the Thrust may be older than the Ross of Mull granite, which is probably of Lower Old Red Sandstone age. The oldest rocks definitely known to be younger than the Thrust are monchiquites and fourchites of a dyke-complex which cuts the mylonites of A'Mhoine; their age is probably Permian.

EXPLANATION OF FIGURE

Fig. 1. Locality Map. The main unornamented areas to the west of the Moine Thrust are Lewisian, Torridonian, and Cambrian; those to the east are Moine Schists. Stipple: Mesozoic and Tertiary. Circles: Old Red Sandstone of Caithness and Moray Firth. Crosses: Plutons mentioned in text.

Inset: Geological map of the monchiquite-fourchite dyke cutting the mylonites of A'Mhoine, about four miles south of Whiten Head.

REFERENCES

Bailey, E. B. 1925. *In*, The Pre-Tertiary geology of Mull, Loch Aline, and Oban. *Mem. Geol. Surv. Scotland.*

Callaway, C. 1883*a*. The Highland problem. *Geol. Mag.*, London (n.s.), **10**, 139–40.

————. 1883*b*. The age of the newer gneissic rocks of the Northern Highlands. *Quart. Journ. Geol. Soc. Lond.*, **39**, 355–422.

Clough, C. T. 1897. *In*, The geology of Cowal. *Mem. Geol. Surv. Scotland.*

————. 1911. *In*, The geology of Colonsay and Oronsay with part of the Ross of Mull. *Mem. Geol. Surv. Scotland.*

Cunningham, R. J. H. 1839. On the geognosy of Sutherlandshire. *Trans. Highland Agric. Soc. Scotland*, **13**, 43.

Flett, J. S. 1914. *In*, The geology of Caithness. *Mem. Geol. Surv. Scotland.*

————. 1935. *In*, The geology of the Orkneys. *Mem. Geol. Surv. Scotland.*

Geikie, A. 1884*a*. Annual Report of the Geological Survey and Museum of Practical Geology for the year ending 31 Dec. 1883.

————. 1884*b*. The crystalline rocks of the Scottish Highlands. *Nature*, 13 Nov., 29–35.

————. 1889. Recent researches into the origin and age of the Highlands of Scotland and the west of Ireland. Lecture to the Royal Institution of Great Britain, 7 June.

————. 1894. Annual Report, etc., for year ending 31 Dec. 1893.

————. 1899. *Ibid.* for 1898.

————. 1907. The geological structure of the North-west Highlands of Scotland. *Mem. Geol. Surv.*

————. 1924. *A long life's work.* London.

———— *et. al.* 1888. Report on the recent work of the Geological Survey in the North-west Highlands of Scotland. *Quart. Journ. Geol. Soc. Lond.*, **44**, 378–441.

Green, J. F. N. 1935. The Moines. (Presidential address.) *Quart. Journ. Geol. Soc. Lond.*, **91**, lxiv–lxxxiv.

Greenly, E. 1927. Benjamin Neeve Peach: a study. *Trans. Geol. Soc. Edinb.*, **12**, 1–11.

Hicks, H. 1878. On the metamorphic and overlying rocks in the neighbourhood of Loch Maree, Ross-shire. *Quart. Journ. Geol. Soc. Lond.*, **34**, 811–18.

————. 1897. On some recent evidence bearing on the geological and biological history of early Cambrian and Pre-Cambrian times. (Presidential address.) *Quart. Journ. Geol. Soc. Lond.*, **53**, lxv–xcii.

Jehu, T. J. 1922. The Archaean and Torridonian formations and the later intrusive igneous rocks of Iona. *Trans. Roy. Soc. Edinb.*, **53**, 165–87.

LAPWORTH, C. 1883. The secret of the Highlands. *Geol. Mag.*, London (n.s.), **10,** 120–8; 193–9; 337–44.

————. 1884. On the structure and metamorphism of the rocks of the Durness–Eriboll district. *Proc. Geol. Assoc.*, **8,** 438–42. *Also in*, *Geol. Mag.*, London, 1885, **2,** 103–6.

————. 1885*a*. The Highland Controversy in British Geology. *Nature*, 8 Oct., 558–9.

————. 1885*b*. On the close of the Highland Controversy. *Geol. Mag.*, London, **2,** 97–106.

MACCULLOCH, J. 1819. A description of the Western Islands of Scotland. 3 vols. London.

MCINTYRE, D. B. 1950. Note on two lineated tectonites from Strathavon, Banffshire. *Geol. Mag.*, London, **87,** 331–6.

————. 1951*a*. The tectonics of the area between Grantown and Tomintoul (Mid-Strathspey). *Quart. Journ. Geol. Soc. Lond.*, **107,** 1–22.

————. 1951*b*. Note on the tectonic style of the Ord Ban Quartzites, Mid-Strathspey. *Geol. Mag.*, London, **88,** 50–4.

————. 1951*c*. Lineation in Highland Schists. *Geol. Mag.*, London, **88,** 150–1.

————. 1952. The tectonics of the Beinn Dronaig area, Attadale. *Trans. Geol. Soc. Edinb.*, **15,** (Campbell Volume), 258–64.

————. 1953*a*. Discussion of paper by Gilbert Wilson. *Proc. Geol. Assoc.*, **64,** 147–9.

————. 1953*b*. Discussion of paper by Anders Kvale. *Quart. Journ. Geol. Soc. Lond.*, **109,** 51–73.

————, W. L. BROWN, W. J. CLARKE & D. H. MACKENZIE. 1954. On the conglomerates of supposed Old Red Sandstone age near Tongue, Sutherland. (*In press.*) *Trans. Geol. Soc. Glasgow.*

———— & F. J. TURNER. 1953. Petrofabric analysis of marbles from Mid-Strathspey and Strathavon. *Geol. Mag.*, London, **90,** 225–40.

MCLACHLAN, G. R. 1953. The bearing of rolled garnets on the concept of *b*-lineation in Moine rocks. *Geol. Mag.*, London, **90,** 172–6.

MURCHISON, R. I. 1859. On the succession of the older rocks in the Northernmost counties of Scotland. *Quart. Journ. Geol. Soc. Lond.*, **15,** 353–418.

————. 1860. Supplemental observations on the order of the ancient stratified rocks of the North of Scotland, and their associated eruptive rocks. *Quart. Journ. Geol. Soc. Lond.*, **16,** 215–40.

———— & A. GEIKIE. 1861. On the altered rocks of the Western Islands of Scotland, and the North-western and Central Highlands. *Quart. Journ. Geol. Soc. Lond.*, **17,** 171–228.

NICOL, J. 1857. On the red sandstone and conglomerate and the superposed quartz-rocks, limestones, and gneiss of the North-west coast of Scotland. *Quart. Journ. Geol. Soc. Lond.*, **13,** 17–39.

————. 1861. On the structure of the North-western Highlands, and the relations of the gneiss, red sandstone, and quartzite of Sutherland and Ross-shire. *Quart. Journ. Geol. Soc. Lond.*, **17,** 85–113.

PEACH, B. N. & J. HORNE. 1914. *In*, The geology of Caithness. *Mem. Geol. Surv. Scotland.*

————. 1930. *Chapters on the geology of Scotland.* Oxford.

PHEMISTER, J. 1948. Scotland: The Northern Highlands. 2nd Ed. *Brit. Regional Geol.*

PHILLIPS, F. C. 1937. A fabric study of some Moine Schists and associated rocks. *Quart. Journ. Geol. Soc. Lond.*, **93,** 581–620.

————. 1949. Lineation in Moinian and Lewisian rocks of the Northern Highlands of Scotland. *Geol. Mag.*, London, **86,** 279–87.

————. 1951. Apparent coincidences in the life-history of the Moine Schists. *Geol. Mag.*, London, **88,** 225–35.

READ, H. H. 1931. The geology of Central Sutherland. *Mem. Geol. Surv. Scotland.*

————. 1934. Age-problems of the Moine Series of Scotland. *Geol. Mag.*, London, **71,** 302–17.

————. 1951. [Discussion of paper by D. B. McIntyre.] *Quart. Journ. Geol. Soc. Lond.*, **107,** 17.

RICHEY, J. E. 1939. The dykes of Scotland. *Trans. Geol. Soc. Edin.*, **13**, 393–435.

RUTLEDGE, H. 1952. The structure of the Fannich Forest area. *Trans. Geol. Soc. Edin.*, **15** (Campbell Vol.), 317–21.

SUESS, F. E. 1931. A suggested interpretation of the Scottish Caledonide structure. *Geol. Mag.*, London, **68**, 71–81.

URRY, W. D. & A. HOLMES. 1941. Age determination of Carboniferous basic rocks of Shropshire and Colonsay. *Geol. Mag.*, London, **78**, 45–61.

WILSON, GILBERT. 1952. A quartz vein system in the Moine Series near Melness, A'Mhoine, North Sutherland, and its tectonic significance. *Geol. Mag.*, London, **89**, 141–4.

————. 1953. Mullion and rodding structures in the Moine Series of Scotland. *Proc. Geol. Assoc.*, **64**, 118–51.

WRIGHT, W. B. & E. B. BAILEY. 1911. *In*, The geology of Colonsay and Oronsay with part of the Ross of Mull. *Mem. Geol. Surv. Scotland.*

APPENDIX

by JOHN M. CHRISTIE, DONALD B. McINTYRE AND L. E. WEISS

Received 11 June 1954

THE VIEWS EXPRESSED in the paper were reached after a detailed study of the literature, and were greatly influenced by the following:

1. The schuppen of the thrust-zone, as shown in the published sections, define a *B*-axis trending NNE.–SSW.
2. Frequent references in the literature to lineations in *a*.
3. The author's observation at Glen Coul of *B*-structures trending NNE.–SSW.
4. The author's observation at Knockan and Eriboll of brecciation along the thrust.

It is stated in the paper that 'the tectonics of the mylonite-zone have never been adequately described, but an investigation which promises to fill this gap has now begun'. After the paper was written, one of us (J.M.C.) spent several months in Assynt studying the structures related to the thrusts. As a result of that work and of subsequent laboratory study of the specimens collected, it was discovered that the lineations in the mylonite-zone, previously taken to be *a*-structures giving the direction of thrusting (e.g. Bailey, *Geol. Mag.*, 1935, **72**, p. 158), are in fact *B*-structures intimately connected with the widespread *B*-structures in the Moine Schists to the east. Following from this discovery, we have made a joint study of a number of exposures of the thrusts from Skye to Fair Aird. It need hardly be said that a great deal of further work is required and is proceeding, but the following new facts are so relevant to the present discussion that we feel they should be recorded here.

1. There has been a single penetrative movement about a common *B*-axis in the Moine Schists, the mylonites above the Moine Thrust, and the deformed Lewisian, Torridonian and Cambrian rocks below. The mylonites do not merely constitute the milled-down schists of the Moine Series. The conspicuous *B*-axis in the Moine Schists must have been imprinted in post-Cambrian time.

2. Many of the 'quartz-mylonites' (including certain deformed Cambrian rocks) associated with the Moine Thrust are not true mylonites *sensu stricto* (see Turner, *Mem. Geol. Soc. Amer.*, **30**, 1948, pp. 10–11, 201), but have undergone partial, sometimes considerable, re-crystallisation. Re-crystallised quartz-mylonites have also been found to the east of the Great Glen (Weiss, McIntyre & Kürsten, MS. in press).

3. Repeated movement is indicated locally (e.g. at Knockan, Loch an Nid, Loch Ailsh and Loch Hope) by brecciation, movement on joints, and even mylonitisation of the older mylonites of the Moine Thrust. An upward age-limit for these movements has not yet been determined.

4. At some localities, notably the Knockan Crag and Loch an Nid, the Moine Thrust-plane is a clean break separating rocks of different composition; but elsewhere (e.g. at Stack of Glencoul) it is represented by a movement-horizon of considerable thickness in which Moine and Cambrian rocks are both involved. Yet again (e.g. at Allt nan Earbagan) it is in places possible to map a thrust-plane on the basis of lithological differences, although the rocks both above and below are tectonites with similar fabrics.

5. Sedimentary structures have been reported from several localities in the Moine Schists. In Strath Oykell the structures, which look like current-bedding, can frequently be seen to be tautozonal about the *B*-axis. It may be that the structures are indeed of sedimentary origin, but, if so, only those of a particular orientation have been preserved (cf. Green, *Quart. Journ. Geol. Soc. Lond.*, 1931, **87**, p. 529).

6. The symmetry of the fabric both of the Moine Schists and of the rocks intimately associated with the thrust seems to be characteristically nearly orthorhombic. The association of these fabrics with large-scale transfer of Moine over Cambrian raises fresh problems.

DISCUSSION

MR. J. M. CHRISTIE pointed out that too much importance may have been attached to the imbricate zones in attempts to determine the direction and sense of movement of the Moine and underlying nappes. In the field, the schuppen-structure is seen only as a repetition of stratigraphic horizons, and the orientations of the intervening thrusts are usually difficult to determine. The speaker had stratum-contoured the major thrusts as shown on the Geological Survey One Inch Sheets, and he had found that the intersections of the thrusts gave a strong maximum indicating an axis of intersection or flexing plunging at 10–20° to N. 100° E. This β-diagram was exhibited. The speaker also exhibited quartz-fabric diagrams of strongly lineated Cambrian quartzites from the thrust-zone showing *B*-axes plunging at low angles to N. 100–120° E.

DR. GILBERT WILSON congratulated Dr. McIntyre on his most interesting and useful review of the story of the Moine Thrust, and on the work he had done in checking the evidence upon which the age of the dislocation had been based. Like Francis Bacon's acquaintance, however, the author had '. . . put that which was most material in the postscript . . .', and left not only the speaker, but probably many others in the room wondering where we went from here! The information given by Dr. McIntyre, that he and Mr. John Christie, working in the Assynt region, have found structures in the mylonites and in the Cambrian rocks of the zone of dislocation, which are co-linear with the south-eastward plunging, minor structures in the Moine Series themselves, is of the greatest importance, but one wonders what is its significance. Does it mean that the movements in the thrust-zone were lateral, normal to these *B*-axes which were briefly mentioned; could these *B*-axes of symmetry be parallel to the direction of tectonic transport, as was suggested by E. M. Anderson in 1948 (*Quart. Journ. Geol. Soc.*

Lond., **104**, p. 90), by A. Kvale in 1953 (*Quart. Journ. Geol. Soc. Lond.*, **109**, p. 51), and by R. Balk in 1952 (*Journ. Geol.*, **60**, p. 415); or are we faced with the possibility that the minor structures, lineations, mullions and the like, of the Moine Series and of the Moine Thrust Zone have really only minor significance? One is reminded of Wegmann's warnings that the magnitudes or scales upon which structures occur in the field must be taken into consideration when assessing their tectonic importance.

Dr. Wilson said that he realised that the facts were still being gathered, but the brief summary of them outlined this evening whetted one's appetite for the final conclusions of Mr. Christie's investigations in Assynt. It will be particularly interesting to compare them with those of Mr. Peter Wilkinson, from the Loch Eriboll area, and of Mr. M. R. W. Johnson, who is studying the same general problems in the ground between Loch Kishorn, Loch Carron, and north of Achnashellach, in Wester-Ross.

DR. J. SUTTON congratulated Dr. McIntyre on an absorbing paper. It was well worth tracing back accepted ideas on Highland geology to the circumstances in which they originated. The speaker believed that much of the growth of the concept of Lewisian inliers came about because the surveyors, fresh from their triumphs in the belt of dislocation, carried ideas developed there eastward into the folded crystalline schists.

Geological myths were not confined to the past, however. He thought there was probably one depicted on the blackboard tonight where Dr. McIntyre had shown the Moine fold-trend as running from NW. to SE. The speaker thought this quite erroneous. The notion was apparently supported by the existence of certain folds, such as those at Fannich and Strath Oykell, which ran in that direction, and by observations that lineations and the Moine petrofabric *B*-axes plunged into the south-eastern quadrant in many localities. The picture changed when every structure over an extensive area was examined. The speaker and Dr. Watson had examined an area in Ross-shire where one third of the all south-easterly plunging lineations noted by Dr. Coles Phillips in the Moines, were located (fig. 5 of Coles Phillips, *Quart. Journ. Geol. Soc. Lond.*, 1937, **92**). They had found a considerable variation in the trend of the linear structures and of the folds. This suggested that an adequate sample of the lineations might not yet have been obtained in other Moine areas.

Secondly they had found that the nature of the major folds could not be deduced with confidence from the small axial structures alone. There were several possible relationships between small and large structures which they had noted in Ross-shire. The linear structures frequently ran parallel to the nearest fold-axis. Sometimes, however, a fold was accompanied by few or no linear structures. Elsewhere the linear structures reflected the interaction of two differently directed folds. Particularly striking examples of this had been found near Loch Monar by Mr. Ramsay.

The Moine folds in Ross-shire ran in a number of directions and appeared on the whole to indicate a westerly or west-north-westerly movement of the overlying beds relative to those below. The classical view on movement in the folded Moines and Coles Phillips petrofabric work could be reconciled and both shown to be substantially correct in Western Ross.

He thought this was worth bearing in mind before reorienting the accepted directions of movement in the thrust-belt in the light of the important new observations made by Mr. Christie. He enquired if the small structures could be related to the large displacements, such as those indicated by the well-known thrust-slice containing rocks identical with those seen in the Foreland near Loch Laxford.

DR. L. E. WEISS noted that the statement in the appendix, that a common *B*-axis exists in the Moines, mylonites and other rocks of the thrust-zone, has at once raised the question of the movements which have affected these rocks. Dr. Sutton suggested that this statement implies a reorienting of the accepted directions of movement in the thrust-belt; the speaker suggested that to look for a *direction of movement* in either the Moines or the mylonites is, at the moment, premature, since it has not yet been established whether the penetrative movements which have occurred in these rocks were of a symmetry and style which can be described in terms of one, two or, indeed, any *directions of movement*. The continual search for a single direction of movement or transport to explain the complexities of the Moine and associated rocks has led to much futile controversy. Dr. Kvale has used the term to describe a direction of extension in a rock-mass, and he has equated this with the believed direction of discontinuous movement on nearby thrust-faults. Consequently he had to reject fabric-symmetry as a guide to symmetry of movement. The example of the quartzite discussed by Dr. Balk, also cited by Dr. Wilson, is one in which under-emphasis of fabric-symmetry has complicated what may be a simple picture. The symmetry of Dr. Balk's diagrams agrees, for the most part, with the symmetry of the movements he suggests.

Since in several localities the Moines rest on top of Cambrian rocks, we are justified in saying that at some period in the history of the thrust-belt there have been large-scale discontinuous movements, probably with monoclinic symmetry. It does not follow that the fabrics we now see in these rocks were produced by and reflect the symmetry of these discontinuous movements. Indeed, the widespread orthorhombic symmetry of fabric (and thus of the *last* penetrative movements in the rocks), observed by Mr. Christie in the thrust-zone, suggests otherwise. Yet to be established is the chronology of penetrative movement, 'thrusting' and crystallisation. Once this has been done, we shall be in a better position to discuss direction and sense of translation, axes of rotation and directions of elongation and shortening in the rocks of the thrust-belt.

MR. P. WILKINSON, in welcoming the paper, wished to take the opportunity of correcting a possible misunderstanding which had arisen from a contribution made to the discussion of Dr. G. Wilson's paper on mullion and rodding structures (*Proc. Geol. Assoc.*, 1953, **64**, p. 145). On the ground east of Loch Eriboll, visible lineations, including quartz-rodding, as described by Dr. G. Wilson, were to be found in quartzites (and to a much lesser extent in quartz-chlorite-sericite schists and sheared Lewisian gneisses) of the Eriboll Nappe. These were described as lineations in *B*. These rocks lie beneath a thrust which separates them from presumed Moine siliceous granulites. Stereographic plotting of macro-lineations shows the Eriboll and Moine Nappes to have homologous fabrics. The ambiguous statement mentioned above apparently led Dr. Wilson to believe that the speaker's belief in a *B*-lineation in rocks close to the thrust was based on comparison of fabric with known *B*-lineations in Moine rocks—actually the reverse of the true situation. This result is in harmony with the findings described by Dr. McIntyre.

Another point, which has been the cause of a great deal of confusion of thought in Highland geology, was the varying usage of the term mylonite. The term had been coined by Lapworth and rigidly and clearly defined by him (*Nature*, 1885, p. 559) with reference to the rocks of the Eriboll region. Unfortunately no type-locality was nominated and his field-notes and maps appear to be of no assistance in this connection. The rocks of the speaker's Eriboll Nappe, i.e. rocks lying between the Eriboll Thrust (?Moine Thrust of Peach & Horne) and the higher Moine Thrust (unnamed by Peach & Horne, above which lie siliceous granulites of presumed Moine age) had been mapped by Peach & Horne on Sheet 114 variously as quartz-schist, 'crush-rocks', frilled schist, schistose marble, and 'thrust' Archaean gneiss. The same tectonic unit, traced south on to Sheet 108, is mapped as 'Mylonised Rocks and Green Schists above Moine Thrust Plane' and on the Assynt Sheet as 'Mylonised Rocks'. The common practice seems to be to refer to all these as mylonites. This is unfortunate as it is often thought to imply that cataclastic structures predominate and hence that thrusting took place in cold rocks. In fact, rocks of the Eriboll Nappe are extensively recrystallised and conform more to Lapworth's definition of 'augen schists'. This accorded with A. G. MacGregor's view (*Trans. Edinb. Geol. Soc.*, 1952, p. 241 *et seq.*) that the Moine rocks were 'hot' when thrusting took place. Further evidence supporting this view was the discovery of apparently syntectonically crystallised green tourmaline in rocks of the Eriboll and Moine Nappes. True mylonites were to be found, but were surprisingly rare, and late movements had been present in the cooling or cold rocks and had resulted in folding and rucking of lineations, faults dislocating the thrust-planes, and local cataclasis. The problem was emphasised by the presence of quartz-chlorite-sericite schists, identical with those in the Eriboll Nappe, well back in the Moine Nappe. Indeed, Cadell had recorded 'Eriboll Schists' in the west face of Ben Hope, four miles east of the main dislocation (*Central Sutherland Mem.*, p. 29).

DR. MCINTYRE, in his reply, said that Dr. Wilson and Dr. Sutton appeared to suppose that he ascribed all importance to minor structures. This was quite wrong; in all his papers on Highland structures the author, as a pupil of Wegmann, had emphasised the scale or scales on which the structures being discussed were displayed, and he had pointed out the necessity for information on as wide a variety of scales as possible. In the present instance, Mr. Christie had presented data ranging from the scale of the thin-section to that of the one-inch map; no wider range of scales was as yet possible. The author (*Geol. Mag.*, 1950, **87**, p. 428) had listed the ways known to him for the determination of the axial-plunge of the grand-scale structures. He wondered how Dr. Sutton and Dr. Watson determined the form of the major folds.

Dr. Sutton was referred to the author's note (*Geol. Mag.*, 1951, **88**, pp. 150–1) on the complex pattern of the fold-trends in the Highlands and to the reference therein to the special interest of the Loch Monar area. Dr. McIntyre had been privileged that afternoon to see some of the results of Mr. Ramsay's work at Loch Monar which, when completed, would undoubtedly prove to be of great importance. In 1951 the author had urged the need for further work on lineations in the Highlands, and he welcomed Dr. Sutton's and Dr. Watson's work in this field. He wished to stress the necessity for the correct identification of *B*-lineations, since the possibility of confusion with axes of internal rotation seemed to be real.

Dr. Sutton's final remark presumably referred to the displacement of the Laxford–Stack line. The author pointed out that, previously, this had been used to give an estimate of the amount of travel of the Glen Coul nappe on the *assumption* of a north-westward direction. A clear account of the argument had been given by Sir Edward Bailey (*Geol. Mag.*, 1935, **72**, p. 158). Dr. McIntyre thought that Dr. Weiss's remarks on direction and sense of movement were particularly timely, and he wished to express wholehearted agreement with them.

It was especially gratifying to find that Mr. Wilkinson's detailed work in Eriboll had led him to conclusions so similar to those put forward in the appendix. The full results of his investigation were awaited with interest. Dr. Wilson had asked where we went from here. Since Dr. McIntyre was shortly leaving for California, he said that he would watch with keen interest the progress of research on the fascinating and difficult structures of the Highlands.

The southern margin of the Cairnsmore of Fleet granite at the Clints of Dromore, Galloway

by F. G. H. BLYTH

Received 16 September 1953; read 5 February 1954

CONTENTS

1. GENERAL DESCRIPTION ... page 224
2. THE GRANITE CONTACT AND MARGINAL ZONE OF INCLUSIONS ... 227
3. FELSPAR PARALLELISM IN THE GRANITE ... 232
4. APLITES AND PEGMATITES ... 233
5. JOINTS
    (a) General statement ... 236
    (b) Orientation diagrams ... 236
    (c) Joints in relation to faulting ... 238
6. QUARTZ-VEINS
    (a) Evidence of faulting ... 239
    (b) Structures associated with quartz-veins ... 241
7. INTERPRETATION OF THE ORIENTATION DIAGRAMS ... 243
8. MODE OF EMPLACEMENT AND AGE ... 246
9. SUMMARY OF CONCLUSIONS ... 248
EXPLANATION OF PLATES ... 249
REFERENCES ... 249
DISCUSSION ... 249

ABSTRACT: The paper discusses the structure of part of the southern margin of the Cairnsmore of Fleet granite, with its marginal zone of xenoliths, the aplite- and pegmatite-veins, the quartz-veins and their internal shear-structures, and the jointing. Prominent vertical joints, trending nearly north and south, are held to be of tectonic origin; they lie parallel to faults which affected the area not long after the emplacement of the granite. The latter is regarded as a high-level pluton, emplaced as magma during a late phase of the Caledonian orogeny.

---

1. GENERAL DESCRIPTION

THE CLINTS OF DROMORE, a line of high granite crags, lie to the north of Gatehouse-of-Fleet station and between five and six miles ENE. of Creetown. They extend for over a mile, from the viaduct which carries the Stranraer line over the Big Water of Fleet, westwards to Mountain End where they diminish in height and merge into the slopes of Craig Hill (Fig. 1). Along the foot of the Clints runs the southern boundary of the Cairnsmore of Fleet granite against Silurian greywackes, shales and grits. As this boundary is traced eastwards or westwards over the slopes, which flank the Clints at either end, it makes no distinctive topographical feature on the hillsides. There is thus a stretch of some 1¼ miles of the boundary which is expressed by prominent craggy topography, rising steeply (in places 300 ft. or more) from the general level of the adjacent drift-covered ground to the south. This part of the granite margin was chosen for detailed study on account of its unusual character and of the almost continuous exposures available.

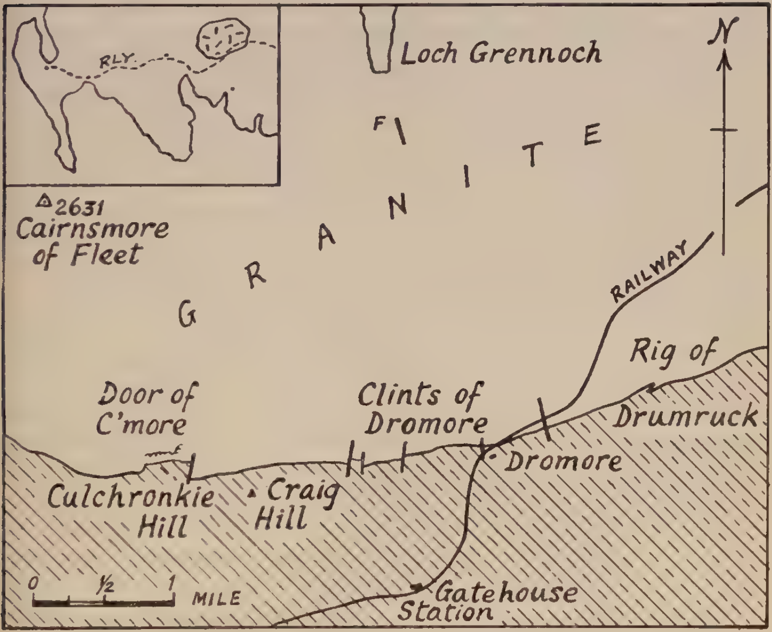


Fig. 1. Locality map; inset, the Cairnsmore of Fleet granite in relation to south-west Scotland

Perhaps the most noticeable feature of the granite crags is their prominent joint-system. Steeply inclined joints strike nearly at right-angles to the line of the cliff for much of its length, and break the rock into slabs about two feet (60 cms.) in width (Plate 5B). They are well seen at the eastern end of the Clints, and can be observed from the railway a little west of the cutting which carries the line through the lower part of the crags. Low-dipping sheet-jointing is absent (Plate 5B). The cutting itself provides over 200 ft. of continuous exposure, and the granite contact can be seen towards its eastern end. Although this section must have been visited by many geologists in the past, no record of it appears to have been published. The ground east of the railway cutting falls to the valley of the Big Water of Fleet.

In its marginal zone the granite carries many xenoliths, and is penetrated by innumerable aplite- and pegmatite-veins; the vein-rocks, however, diminish in number broadly from east to west along the stretch of margin under discussion, and also northwards away from the margin. Large numbers of quartz-veins are also present, and in general have very regular directions; their structural significance is discussed later. The relationships between aplites, pegmatites, quartz-veins and the granite are epitomised in the exposure sketched in Fig. 2a. The aplites and pegmatites were the first to be injected into fractures formed in the granite; both are cut by quartz-veins, which are, therefore, post-aplite. A little later still, shearing of the granite and its vein-rocks took place; this is shown by the parallel fractures crossing the quartz-veins like fracture-cleavage, and extending occasionally through the granite. The features outlined above—zone of xenoliths, vein-rocks, quartz-veins, joints and fractures—are discussed in succeeding sections of this paper.

The summit-line of the Clints ridge is broken by a series of hollows or gullies, which cross it in a nearly north and south direction. The largest of these, known as the Deep Nick of Dromore (Plate 5A), is a wide, steep-sided hollow about 100 ft. deep, with a floor some 50 ft. across, and is probably of glacial origin. The Pleistocene ice moved approximately from north to south over the area, incidentally bringing erratics of pink muscovite-granite from the interior of the granite outcrop and depositing them high up on the northern slopes of the Clints. It is suggested that the various hollows or 'nicks' are located on lines or zones of fracture within the granite, where the rock was less resistant to glacial erosion than it was on either side. From the summit of the ridge the ground falls gently northwards for 1½ miles to a peat-covered depression within the granite outcrop, south of Loch Grennoch (Fig. 1). Seen from either its east or west end, the Clints feature thus resembles an escarpment, with the dip-slope to the north.

A general account of the Cairnsmore of Fleet granite has been given by Gardiner and Reynolds (1937), who distinguished marginal biotite-granite from biotite-muscovite-granite in the interior of the mass, and postulated separate intrusions of the two varieties. They gave a specific gravity map of the pluton, and referred briefly to the aplites and other vein-rocks. They also mentioned the railway cutting near Dromore, but gave no details of the contact other than saying that 'granite with aplitic apophyses is seen penetrating the altered rocks' in the cutting (*loc. cit.*, p. 298). A short statement of the contact metamorphism, shown by rocks near parts of the granite margin, was included in the paper.

Pringle (1935, p. 55) refers only briefly to the Cairnsmore of Fleet mass, which is described as a coarse-grained biotite-granite, with muscovite sometimes present. It is surrounded by a 'broad ring of metamorphosed sediments'.

Teall (1899, p. 618–19) described the pluton as a biotite-granite with both alkali-felspar and oligoclase, in which muscovite was occasionally present. He discussed a series of specimens taken from different parts of the granite area, and recorded that some of the samples contained pink microcline, and some a few grains of hornblende, but the variation in mineral content among them was not large. He also noted the occurrence of veins of aplite and pegmatite, and said that, of the Galloway granites, ‘the most acid rocks are represented by the muscovite-biotite-granites of the Cairnsmore of Fleet mass’. Teall also gave an account of contact-metamorphism produced by the granite, incorporating the work of M. I. Gardiner (1890).

The 1878 Memoir, accompanying Sheet 4 of the 1-inch map of Scotland, gave a reference (p. 19) to veins of ‘fine-grained granitic rock’ occurring ‘all through the heart of the coarse-grained granite’, and the railway cutting near Dromore was mentioned as showing one of the best examples of these veins.

According to my own observations, the granite, along its southern margin, shows only a small range of variation in mineral composition. Measurements by point-counter on thin sections from well-separated localities (extending over a distance of more than three miles) gave the following average for the mode:

Quartz	30.6	(+1.5, −1.5) %
Microcline-perthite	26.1	(+3.2, −5.2)
Plagioclase	33.1	(+3.7, −7.1)
Mica (mainly biotite)	8.4	(+2.4, −2.2)

(Figures in brackets are the maximum deviation above and below the average for each mineral.)

2. THE GRANITE CONTACT AND MARGINAL ZONE OF INCLUSIONS

The country-rocks in the belt of ground to the south of the granite margin near Dromore are grits, greywackes and shales of Llandovery age (Horne, 1896). They have undergone a thermal metamorphism, and, near the contact, the grits, which here predominate among the country-rocks, become biotite-quartz-hornfelses; but the metamorphism is outside the scope of the present paper and will not be further discussed. The strike of the country-rocks south of the Clints is nearly east and west, swinging to the regional direction of about ENE. on the Rig of Drumruck. The beds are generally vertical or dip steeply within 10° of the vertical.

The railway cutting already referred to, in which the granite contact is exposed, is situated 250 yds. N. by W. of Dromore;[1] details of the north side of the cutting and the adjacent ground are shown in Plate 6B. Hornfelsed sediments penetrated by veins of granite and aplite, and broken by small faults, occupy the first 160 ft. of the north side (going from west to east); granite is exposed over the remaining 65 ft. of the cutting, and makes a sharp, steep contact with the sediments, which are here mainly massive grits.[1] These have a broken appearance, and bedding is obscured; but a short distance away from the contact the sediments strike regularly nearly east–west, and carry thin aplite-veins. The contact is traceable in the ground at the top of the cutting, and for a short distance trends WNW. with a northerly dip of about 75°. There is no zone of transition between granite and sediments at the contact, which appears to be the result of mechanical injection. The granite retains its coarse texture up to the contact; this may imply that its temperature during emplacement was low, so that little chilling occurred, though other interpretations are possible.

---

[1] Map reference: Kirkcudbright 40 NE.

From the east end of the cutting the granite boundary can be traced in rock-faces on the slopes down to the Big Water of Fleet where, a little south of the viaduct, it passes under a cover of alluvium, emerging again on the rising slopes of the Rig of Drumruck (Plate 6A). Several veins of garnetiferous aplite are exposed on either side of the track between the cutting and the viaduct. The general direction of the contact over this stretch is N.73°E., roughly parallel to the regional strike of the sediments.

When the contact is traced westwards from the cutting in a series of rock-faces, which lie at the foot of the steep crags, it is found to be a somewhat irregular line. The granite holds many large enclosures of hornfels in its marginal zone, and appears to penetrate the sediments in tongues which run parallel to the vertical bedding-planes, which here have an average strike of N.85°E. There is thus a series of local parallel contacts, one of which is sketched on Plate 6B. The granite occasionally cuts across a bed of grit via cross-joints and then follows a course parallel to the bedding. Many of the hornfels enclosures lie with their bedding-planes approximately vertical and parallel to the general strike, but others are turned so that their length makes an acute angle with the direction of the contact.

One large rock-face, situated just north of the west end of the railway cutting, shows granite partly covered with a skin of hornfels an inch or two thick, welded on to the granite; the face is about 80 ft. long and slopes at 45° south. Steeply inclined pegmatite- and aplite-veins here cut both the granite and its enclosures. At a slightly higher level, and 140 ft. due west of this face, other xenoliths are well displayed in the granite. This group of enclosures lies about 80 ft. in from the contact; few xenoliths have been observed farther into the granite than this.

The zone of enclosures at the granite-margin is thus a relatively narrow one, probably not more than 100 ft. in width. It can be traced at intervals along the foot of the Clints, though the best exposures are those described above; its occurrence is taken as evidence for mapping the position of the contact when the latter is not exposed. The hornfels xenoliths often have sharp margins against the granite, which retains its coarse texture up to them. Some xenoliths contain occasional felspar porphyroblasts, and their margins are less sharp and distinct, indicating that a certain amount of softening and metasomatism has taken place. The extent to which this has occurred is, on the whole, small, and a relatively low temperature of emplacement of the granite may be again indicated.

---

[1] Gardiner & Reynolds (*loc. cit.*, p. 298) record also biotite-cordierite-hornfels and biotite-andalusite-schist from this locality.

The localities just described lie at levels of 425 to 450 ft. above O.D. The xenolithic granite, as it is traced westwards along the foot of the crags, appears to be set back to the north below the second 'nick' which breaks the skyline, and then crops out near the 550-ft. contour (Plate 6A). This is some 700 ft. due west of the cutting. A detail seen near here is sketched in Fig. 2c; a rock-face shows hornfels adhering to granite along a vertical surface. The hornfels slab is about six inches thick and has a distinct fracture-cleavage pattern, which indicates an upward movement of the granite-wall on the north relative to the south wall (denuded). About 400 yds. farther west, after some drift cover in the intervening ground below the third 'nick', the marginal granite is again seen, now near the 725-ft. contour. Good exposures of xenolithic granite occur at about the 675 or 700-ft. contour, below the Deep Nick which crosses the Clints 300 yds. west of the point mentioned above. On this evidence the granite boundary is drawn here, set forward a little to the south. The relationships between granite, hornfels enclosures and joints which cross both, are shown in Fig. 2b.

The marginal granite with enclosed slabs of hornfels is again well exposed at the foot of the southern slopes of Mountain End, at the 800-ft. contour or a little higher. Steep granite slabs here have 'skins' of hornfels. One large raft of hornfels is broken by a fault-breccia which forms a vertical zone two feet wide; the vertical bedding of the hornfels, adjacent to the east wall of this zone, has been dragged round to the north, indicating a southerly movement of the wall relative to the west side. The breccia-zone strikes at 155° and can be traced upwards in the rock-face; when the granite above the hornfels is reached, the breccia grades into a quartz-vein which traverses the granite in the same direction. This occurrence affords a demonstration of the connection between faulting and quartz-veining: the quartz seals fractures in the granite which are expressed as faults in the hornfels. The several off-sets in the granite boundary mentioned above are attributable to post-emplacement faulting, which is discussed on p. 245.

On the northern slopes of Craig Hill, west of Mountain End, the granite

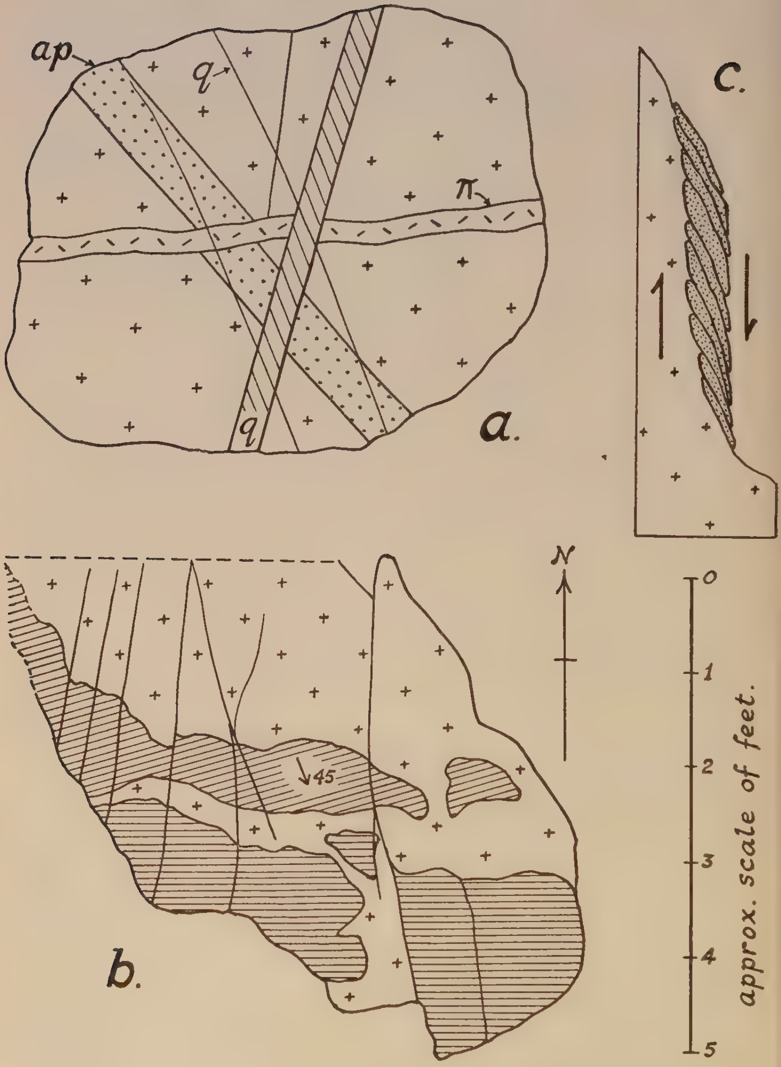


Fig. 2. (a) Rock-face of granite, about 5 ft. long, traversed by veins and joints; (b) Sketch of rock-face on the south-east side of the Deep Nick, to show relations between granite (crosses), enclosed hornfels (lined), and joints; (c) Sketch of hornfels (stippled) adhering to vertical face of granite, below the 2nd 'nick'

boundary can be traced in a series of exposures a little above the 1000-ft. level, but it forms no conspicuous feature as at the Clints. The vertical sediments on Craig Hill strike nearly east and west, and in places carry veins of aplite and of granite, often parallel to the bedding. One granite vein, at about the 950-ft. contour and NW. of Gatehouse station, is several feet in width and is crossed by many vertical joints running nearly north and south (G on Plate 6A). Between these joints the granite is broken by other shears trending NW., giving a fracture-cleavage pattern. A few of the NW. shears also break the adjoining grits. Some 300 ft. to the SE. of this exposure, and about 600 ft. south of the main granite boundary, another vein of coarse granite makes a small feature on the hillside.

Pelitic sediments exposed in rock-faces near the 1025-ft. contour, 1¼ miles NW. of Gatehouse station, show small drag-folds (Fig. 3); the strike here is 86°,[1] and the drag-folds pitch (or plunge) westwards at about 15°. If this distortion was produced by the emplacement of the granite, as seems likely, it would indicate a mainly vertical movement combined with a smaller left-handed horizontal component. Other drag-structures in the sediments, associated with small faults, have also been observed near the same locality, which is within 100 ft. of the granite margin (*E* on Plate 6A).

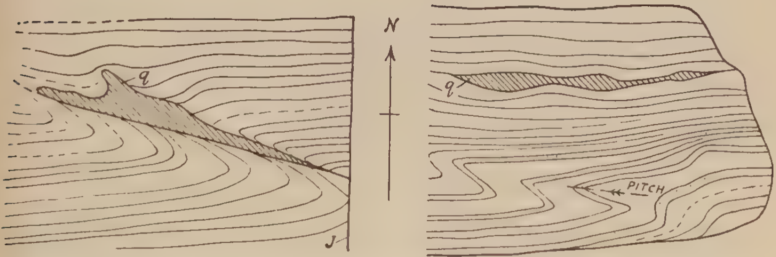


Fig. 3. Sketches of drag-folds in aureole sediments on Craig Hill (Locality *E* on Plate 6A). Each sketch represents a width of about 18 inches across strike

Farther west along the northern slopes of Craig Hill, towards Culcronkie Hill (Fig. 1), the granite boundary is lost beneath a cover of drift and peat, but on the evidence of a few exposures and of boulders it is drawn at about the 1025-ft. contour, which trends parallel to the east–west strike of the sediments. The boundary is probably displaced to the north by a fault which passes between Craig Hill and Culcronkie Hill; on the western side of this fault the massive granite crags of the Door of Cairnsmore rise steeply from the peaty ground at the head of the Culcronkie Burn.

---

[1] Directions, such as strike, are given as bearings measured clockwise from true north.

The field observations described in this section provide evidence of an upward movement of the granite at its margin along the line of the Clints, which may be summarised here. We have (i) the occurrence of the crags themselves, which are in contrast to the relatively featureless country to the east or west; (ii) fracture-cleavage structures observed in the vertical hornfels enclosures near the granite margin (p. 229); (iii) gently plunging drag-folds in the sediments adjacent to the granite margin; (iv) evidence from the displacement of joints and veins which is given later (p. 241). The upward movement was a local phase, late in the history of the pluton, and its extent was controlled by the presence of other fractures which had torn the granite margin, as discussed on p. 246.

3. FELSPAR PARALLELISM IN THE GRANITE

Although the rock of the Clints is not, in general, porphyritic, it occasionally contains small felspar phenocrysts. A search was made for evidence of orientation structures in the granite, and at the five localities, listed below, felspar-parallelism was seen:

(i) Granite exposed about 310 yds. WNW. of the west end of the railway cutting shows parallel porphyritic felspars which are oriented at 96°. The phenocrysts are not numerous.

(ii) Near the first 'nick' (east end of the Clints), in some of the lower exposures porphyritic felspars possess a rough orientation at 98°.

(iii) Near the top of the crags, between the first and second 'nicks', and nearer the latter, there is a rough orientation of scanty porphyritic felspars at 88°. In this part of the granite, also, some parallelism of micas in vertical planes is present, in the same direction as the felspars.

(iv) At the top of the crags, a little west of the second 'nick', several granite slabs show orientation of felspars, the average direction being 88°.

(v) At the top of the crags, 1000 ft. west by north of the west end of the railway cutting, the granite contains scanty porphyritic felspars which are aligned at 98°. Their parallelism is not conspicuous because individual felspars are several inches apart and are separated by areas of normal granitic texture.

Some degree of orientation of porphyritic felspars is thus locally discernible in the eastern part of the granite crags, though it is not apparent in the greater part of the mass. It may be taken as indicating local laminar flow in the rock, the strike of the surfaces of flow being nearly east and west (parallel to the strike of the aureole sediments). This fact is important in the interpretation of the joints in the granite. A series of traverses in from the granite margin failed to yield any further examples of felspar or other mineral orientation.

At one or two localities a vague lineation in the non-porphyritic rock is seen, the groundmass felspars being aligned and quartz filling the spaces between them. This appears to be a restricted effect which may only occur in the proximity of faults, and would then indicate that the granite came locally under the influence of stresses during consolidation.

4. APLITES AND PEGMATITES

The abundance of quartzo-felspathic vein-rocks is one of the more outstanding features of the area under discussion. As already stated, these veins are especially numerous in the eastern part of the Clints, where many aplites fill vertical fractures which trend nearly east and west, and range in width from a fraction of an inch to about two feet. This group of east–west aplites represents a definite extension in the north–south direction, which took effect after the emplacement of the granite. From measurements made near the west side of the third 'nick', the horizontal extension is estimated to amount locally to 8 or 10%. Other aplites, steeply inclined, follow different directions, and a few occupy gently dipping joints or fractures, as discussed below.

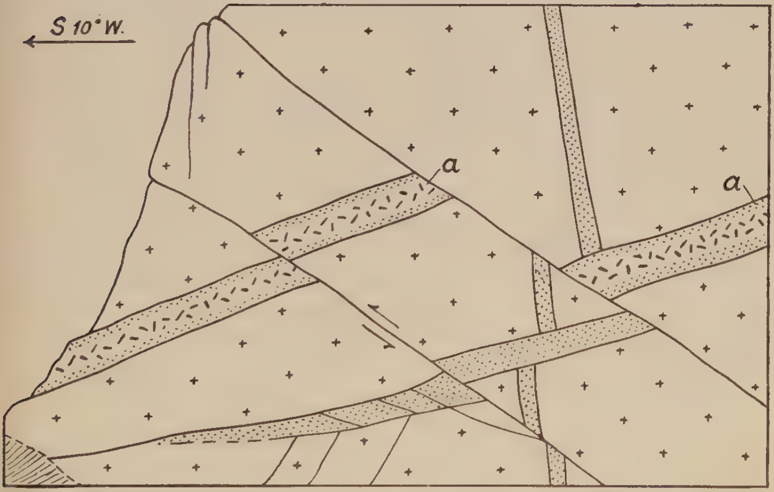


Fig. 4. Sketch of vertical rock-face of granite, on west side of the 2nd 'nick'. The granite is traversed by an 8-in. wide vein (*a*) of pegmatite with aplite margins, and by other aplites (stippled) and fractures

The minerals of the aplites are quartz, microcline, oligoclase and muscovite; a pink garnet is often, but not always, present.

Pegmatite-veins, composed of quartz, microcline-perthite, and muscovite, occur somewhat less frequently than the aplites, but are numerous at the eastern end of the Clints. They commonly cut across aplites, and are thus generally later in order of injection (see Fig. 5a); many examples have been sketched and recorded, but cannot be reproduced here. Occasionally, however, aplites cut the pegmatites, as, at the top of the crags north-west of Dromore, where a nearly north–south pegmatite vein three inches wide is crossed by a five-inch aplite in an E. by S. direction; both are intersected by vertical NW.–SE. joints, which also pass through the granite and are last in order of formation.

It is clear that the episodes of vein-filling by pegmatites and aplites were more or less simultaneous. This is borne out by a number of observations in which the two rocks are associated in the same vein. In the example shown in Fig. 4, an 8-inch vein has aplite margins on either side of a pegmatite centre; there is no sharp contact between the two, but the aplite merges into the pegmatite. Occurrences of this kind are on record from many granite areas. Apart from considerations of viscosity and content of volatiles, it has been suggested by Shand (1949) that whether pegmatite or aplite crystallises from a given melt depends on the physical conditions of cooling: very slow cooling without disturbance would lead to the formation of large crystals, less slow cooling and agitation of the melt would give more centres of crystallisation.

An aplite-vein five inches wide which cuts the granite in the eastern wall of the second 'nick', strikes at 98° and dips south at 75°. It has sharp boundaries against the granite. The upper part of the vein is cut and moved outwards about ten inches by a low-dipping thrust, as shown in Fig. 5a. The severed ends of the aplite are dragged round a little by the movement. A second and narrower vein, parallel to the first, partakes of the same displacement. The thrust-fracture is filled by a narrow pegmatite, suggesting that the necessary fluid was available to enter the fracture as or when the latter was formed. This structure recalls the marginal overthrusts of other writers (Balk, 1937; Cloos, 1931). Expansion of the upper part of the granite pluton along such minor thrusts relieved stresses resulting from the pressure of still fluid parts of the interior on a solidified outer shell. Other instances of similar movements on gently dipping thrusts have been observed in the area.

A similar structure occurs in the opposite wall of the second 'nick', where a vertical aplite is broken and shifted about twelve inches by a small thrust. The shift is in the same sense as that described above; the thrust has a similar direction and dip (25°N.) and is filled by a thin quartz-vein.

The normals to the directions of eighty-four aplites and pegmatites were plotted on a stereogram, from which the contoured diagram of Fig. 6a was prepared. The diagram shows a maximum frequency of orientation at N.10°E., corresponding to a vein-direction of 100. It is to be noted that this direction corresponds closely with that of felspar parallelism (p. 232).

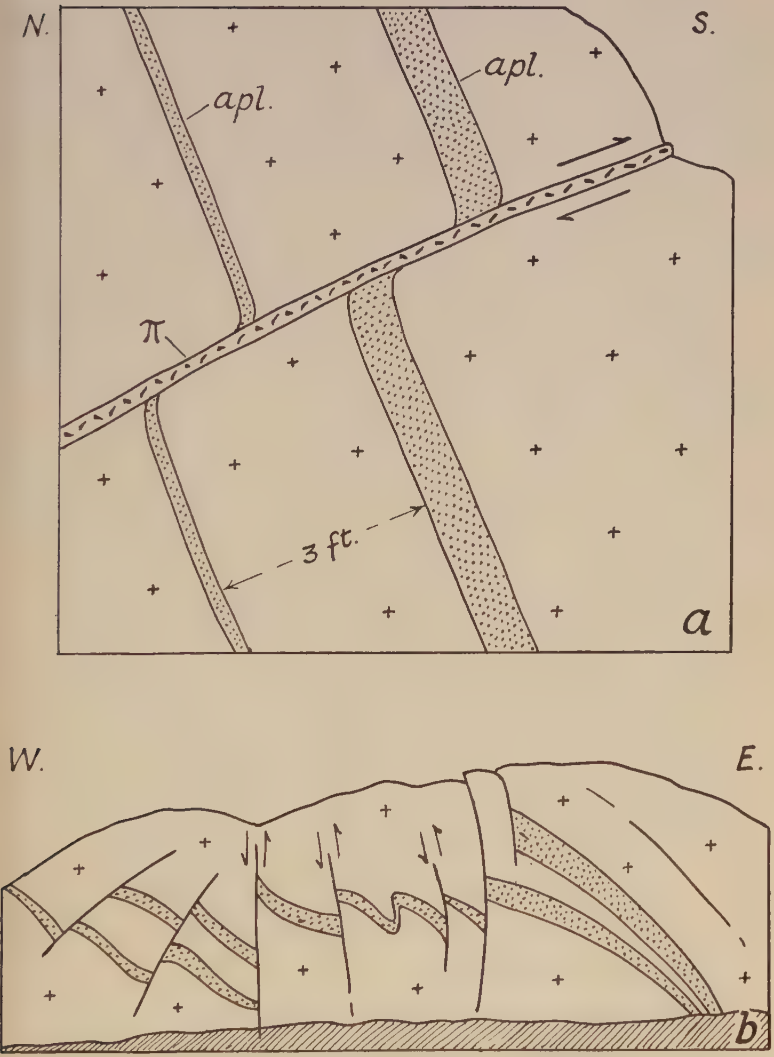


Fig. 5. (a) Aplite-veins severed and moved forwards by a small thrust, which is filled with pegmatite; sketched from the eastern wall of the 2nd 'nick'; (b) Fractured quartz-veins in granite, on southern face of Mountain End (see p. 241)

5. JOINTS

(a) **General statement.** Although it is convenient here to treat joints and quartz-veins in separate sections, most of the quartz-veins (i.e. quartz-filled joints) have a common pattern with many of the joints, and both are related in origin. Reference has already been made to the prominent jointing displayed in parts of the granite. At the eastern end of the Clints, for example, smooth, regularly spaced, joints strike at about 160° and dip 75° west (Plate 5B), and thus intersect the granite margin nearly at right-angles. Other sets of joints are also present here, but are less well developed; the north-north-westerly set is conspicuous and seems to be superimposed on the rest. Other localities where steep, regular joints are well developed include the crags known as the Door of Cairnsmore (about 1¼ miles west of Mountain End, Fig. 1), and those immediately west of Loch Grennoch Lodge (three miles north of Mountain End); at both these localities the joints trend nearly north and south and break the granite into remarkably regular, nearly vertical slabs two feet (60 cms.) or more in width.

High granite crags, which form marked topographical features, go with regular and prominent jointing in this granite country; and I consider these vertical sets of joints to have had a tectonic origin. The crags, at a number of places, can be shown to end at faults, to which the joint-trends are parallel, and the joints were probably formed by the same system of stresses which ruptured the granite along the lines of faulting.

The general absence of gently dipping sheet-jointing, in at least the marginal part of the granite, is noteworthy. Sheet-jointing is often controlled by the shape of the roof or walls of an intrusive igneous mass, or is parallel to the general topographical surface. The Cairnsmore of Fleet granite came into position among mainly vertical sediments, and its southern boundary is essentially vertical. On this account, low-dipping sheet-joints would not be expected. Nearly vertical joints which lie parallel to the boundary are present, however, but are not so conspicuous as the steep northerly trending joints referred to above. In the marginal zone of xenoliths (p. 228) joints in the granite cut through large enclosed masses of sediment without deviation. This is seen, for example, immediately south of the Deep Nick of Dromore, at the foot of the crags of Mountain End, and on the Rig of Drumruck. Evidently the granite was almost, if not completely, rigid when the joints were formed.

(b) **Orientation diagrams.** Stereographic plots (lower hemisphere) were made of joint directions in the Clints area, and of open joints and quartz-veins together, and the contoured frequency diagrams prepared from them are shown in Figs. 6C and 6D respectively. The two diagrams are closely similar; both have two frequency maxima at 72° and 89°, of nearly equal intensity, corresponding to groups of vertical joints at 162° and 179°. The directions 72° and 89° are also the same as those for two of the three maxima for quartz-veins plotted separately (see Fig. 6B). It is inferred, therefore, that both open joints and quartz-filled joints (i.e. quartz-veins) in the two directions had a common origin; whether a particular fracture received a filling of quartz may have depended on the ease or otherwise with which the siliceous fluids could gain access to it.

Two subsidiary maxima in Fig. 6D lie at 176° and 198°, nearly corresponding to vertical sets of joints at 86° and 108°. The pole marked 5% in the

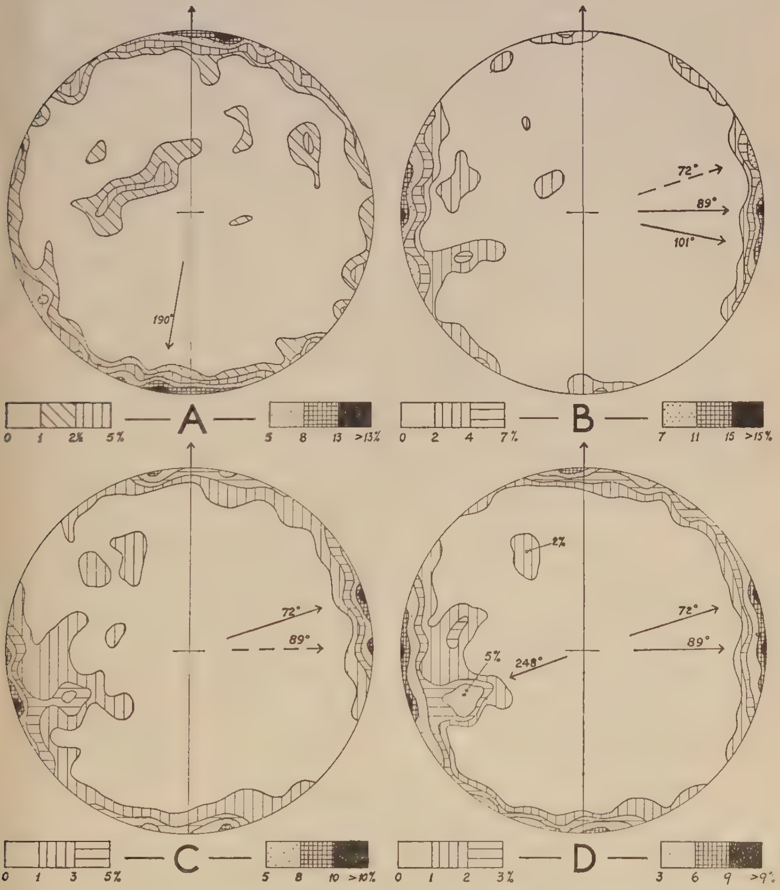


Fig. 6. Orientation diagrams: A, aplites and pegmatites; B, quartz-veins; C, joints; D, quartz-veins and joints together. Directions of principal maxima shown by arrows, with bearings from north in degrees

SW. quadrant of the figure corresponds to joints striking at 158° and dipping 60° west. The directions of joints of maximum frequency are plotted in Fig. 9, and the interpretation of these results is discussed on p. 244. It may be noted here that the preferred directions of joints given above (viz. 162° and 179°) correspond to those of fractures in sheared dykes which occur in neighbouring ground to the south (Blyth, 1949, fig. 5, p. 406).

(c) **Joints in relation to faulting.** The hollows which break the line of the Clints ridge transverse to the granite margin have been referred to above as 'nicks', the largest of them being the Deep Nick of Dromore (as named on the O.S. 6-inch sheet). A sketch plan of the first hollow is given in Fig. 7a, and on it prominent joint-surfaces and veins are marked. The general trend of the hollow is about 160°, parallel to many of the steeply dipping joints. On the west side of the hollow, a vertical band of broken rock showing fracture-cleavage indicates an upward movement of its west wall relative to its east. The fault through this hollow probably runs at 158° or 160°; a parallel fault in the second hollow displaces the granite boundary by a horizontal distance of over 100 ft. (Plate 6A).

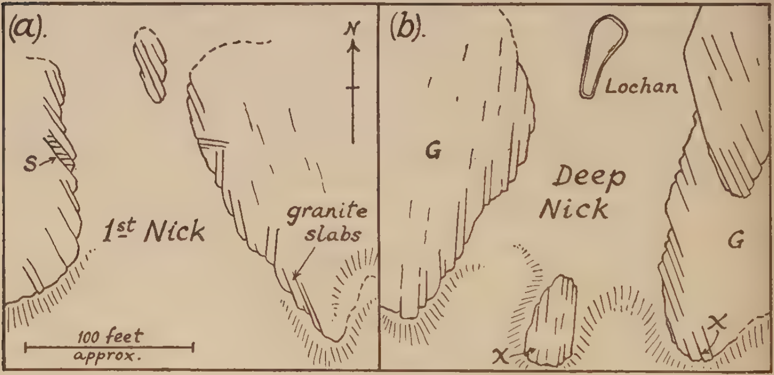


Fig. 7. Diagrammatic sketches of joints in granite at (a) the 1st 'nick'; (b) the Deep Nick of Dromore. G=granite; X=xenolithic granite; S=sheared zone

The main trend of the Deep Nick is at about 12°, approximately as shown on the 6-inch map; but at its southern end it divides into two parts, and the eastern branch trends at 163° (Fig. 7b). Granite crags between the two branches of the hollow carry many vertical joints at 185°, and at their southern extremity the marginal zone of inclusions is seen. In the main eastern wall of the hollow, prominent joints, which strike at 160° and dip 55° west, break the rock into regular slabs. At a higher level on this eastern side the joints have a similar strike but steeper dip (about 80°);

many parallel quartz-veins here are associated with a slight reddening of the granite which extends for ¼ or ½ inch (6 to 12 mm.) into the rock on either side of a vein. The granite of the west wall of the Deep Nick (north end) has many joints in a north–south direction, dipping 70° west, and a nearby exposure shows vertical quartz-veins which cut the granite in a similar direction. It is probable that the Deep Nick is located at a point where two faults break the granite: one fault trends at about 160° and occupies the eastern branch of the hollow, the other trends between 0 and 5° and lies along the western branch (Plate 6A). The faults account for small offsets in the granite margin and for the local discontinuity of the east–west crag feature.

Other faults crossing the line of the Clints are shown on Plate 6A, and it may be useful here to summarise the evidence for considering the 'nicks' or hollows as being located along lines of faulting:

(1) There are distinct shifts in the steep crag feature opposite the 'nicks', and the marginal (xenolithic) zone of the granite also appears to be offset at those points.

(2) There is a stepping-up of the level of the top of the crags along the line of the Clints from east to west, successive steps occurring at the positions of the 'nicks'.

(3) The hollows show a general parallelism to regular joint directions in the granite which elsewhere are parallel to demonstrable faults.

(4) At several of the hollows, groups of quartz-veins are present and lie parallel to the trends of the presumed faults (see p. 240).

The hollows, being located along lines of weakness in the rock, probably resulted from the plucking and scouring of the broken rock by southward moving ice. Various indications suggest some vertical movement on these transverse faults (p. 232), occurring after the main movement, which was horizontal (see p. 245).

The trend of joints occurring farther afield may be briefly noted. On the Rig of Drumruck, near its summit, granite appears to vein the sediments, the veins running parallel to the strike of vertical bedding-planes; vertical joints at 163° cut both granite and sediments here, and other joints run at 98° and 143°. At an exposure 100 ft. west of the summit, a smoothed joint-face at 163° and dipping 60° west, carries nearly horizontal slickensides which pitch south at a small angle. This indicates horizontal movement, and similar evidence is occasionally seen at other localities in the wider area.

6. QUARTZ-VEINS

(a) **Evidence of faulting.** Numerous quartz-veins are conspicuous in many of the granite exposures; and the connection between fracturing and quartz-veining at one locality has already been referred to (p. 229). They vary in width from a fraction of an inch up to 12 in. (30 cms.)

or more, and commonly occur in parallel vertical sets, which frequently strike between 360° and 345°. These directions, which are similar to those of joints already described, are nearly at right-angles to the granite margin. They are accordant with the two main frequency maxima in Fig. 6B. Some quartz-veins are associated with a slight reddening of the granite at their margins (see p. 239).

Few exposures of granite are without some thin veins in one direction or another, but some localities show a concentration of quartz which commonly fills parallel fractures or may form stock-works. One such concentration is seen at the eastern end of the Clints, about 100 yds. west of Little Cullendoch (marked *A* on Plate 6A). Granite is exposed here as a low crag with smoothed top, and is traversed by many parallel or subparallel quartz-veins which strike in directions from 158° to 163° and dip steeply west at about 80°. Some 300 yds. south of this locality, a flat-topped granite ridge (*B* on Plate 6A), nearly 100 ft. long and over 20 ft. wide, is broken by a network consisting of major veins which strike north–south, from which smaller veins branch off. The veins stand up in relief on the weathered surface of the country-rock. The granite was evidently broken by many fractures and re-sealed by rising siliceous fluids. This fracture zone confirms other evidence pointing to the presence of the nearby fault which terminates the Clints feature at its eastern end. East of the fault the ground falls sharply to the alluvial flat of the Big Water of Fleet.

Another concentration of quartz-veining occurs at the western end of the Clints about 850 ft. NNW. of the main summit of Mountain End, and a little above the 875-ft. contour on ground falling to the north. Here a large exposure of granite, elongated north and south, stands out in relief (locality *C* on Plate 6A). This granite is sheared and veined in an intricate manner. It is traversed by a nearly vertical belt of fracturing, between 15 and 20 ft. in width, in the direction N.5°E., within which the rock has been completely shattered and re-cemented by quartz. The surface is rough and jagged from projecting masses of quartz, which stand up a little above the intervening host-rock. This fracture-belt or fault must have been formed late in the cooling history of the granite. Detailed structures observed here indicate a left-handed tear movement, which may possibly be combined with a vertical movement, on the dislocation.

Another exposure, which is also elongated north and south, some 650 ft. (200 m.) south by east of the locality described above, shows severely fractured granite veined with a network of quartz-veins. This exposure (*D* on Plate 6A) is at about the 900-ft. contour on the east side of the hollow between the two summits of Mountain End. A prominent quartz-lined face here trends at 13° and dips at 85° west. The eastern side of the exposure is a quartz-reef in the granite, and is broken by vertical shears at 10°. The quartz evidently seals a large fracture, and the evidence as a whole points to a fault, or fault-group, which is nearly parallel to that at locality *C* (above). Evidence from vein displacements and fractures seen on the flat upper surface of the mass again indicates a left-handed tear movement (cf. Fig. 8*h*). At the southern end of the mass, however, a vertical east–west face about 4 ft. (1¼ m.) long shows inclined quartz-veins, up to three inches (8 cm.) in width, broken repeatedly by vertical or nearly vertical shears (Fig. 5*b*). The walls of the latter are displaced relative to one another, the right-hand side being moved upwards relative to the left in each case. Each shear displacement is only a few inches, but the aggregate amounts to several feet, and this occurs in a horizontal distance of 4 ft. If similar shears are present in the (unexposed) rock on either side, the total vertical movement would be considerably more. There are thus both horizontal (north–south) and vertical components of movement indicated here.

A zone of faulting is therefore present at Mountain End. Between the two nearly parallel lines of fracture described, there is ample room for one or more other faults which would occupy the depression between the two summits and account for the broken topographical feature. A fault is also needed to account for the shift of over 200 ft. (in plan) of the granite margin near here, as mapped by the zone of xenoliths. This Mountain End fault-zone, if continued northwards, would pass close to Loch Grennoch, which lies at about the centre of the granite area (Fig. 1), and there is evidence of faulting at that locality; but this wider matter is outside the scope of the present paper and must await later discussion. The structural details, from which the faulting is deduced, have been given above at some length because I believe the Mountain End–Loch Grennoch fault to be a major line of dislocation in the area. The age of the movements in relation to the history of the granite is discussed on p. 246. At other points where the Clints ridge is broken by faults there is also evidence connecting the presence of quartz-veins with fracturing of the granite mass in response to stresses operating after its emplacement.

(b) **Structures associated with quartz-veins.** Minor structures, involving displacements of veins or occurring within them, indicate the direction and sequence of movements which have affected the rocks. Many details of fractured and displaced veins have been recorded, and a selection of these is illustrated in Fig. 8, in which the sketches are plans unless otherwise stated.

(i) Aplites are cut and displaced by quartz-veins: Fig. 8*a* shows a right-handed horizontal movement of a few inches in the direction 10°. Fig. 8*b* illustrates a three-inch wide vertical aplite-vein displaced six inches by a fracture (without quartz-filling) in the direction 138°.

(ii) Quartz-veins are cut and shifted by later fractures. In Fig. 8*c* a vertical vein, 1½ inches wide in the direction 153°, has undergone a left-handed displacement along a north–south shear. Fig. 8*d* shows another vein, in the direction 20°, cut and shifted by a quartz-filled fracture at 168°. In Fig. 8*e* a nearly east–west vertical quartz-vein is broken and displaced by steeply dipping fractures in the direction 168°; one horizontal movement here measures 14 in.

(iii) Quartz-veins sometimes break and displace joints in the granite, as in Fig. 8*f*; the vein shown is itself crossed by later joints (at 86°), but not shifted by them.

(iv) Quartz-veins with internal shear structures (i.e. shears within the veins) have been observed in considerable numbers. The shearing is either (a) of fracture-cleavage type; or (b) in the form of parallel fractures *en échelon* which make a small acute-angle with the walls of the vein: this structure will be referred to as the Reidel type, from its resemblance to fracturing produced experimentally by Reidel (see p. 245).

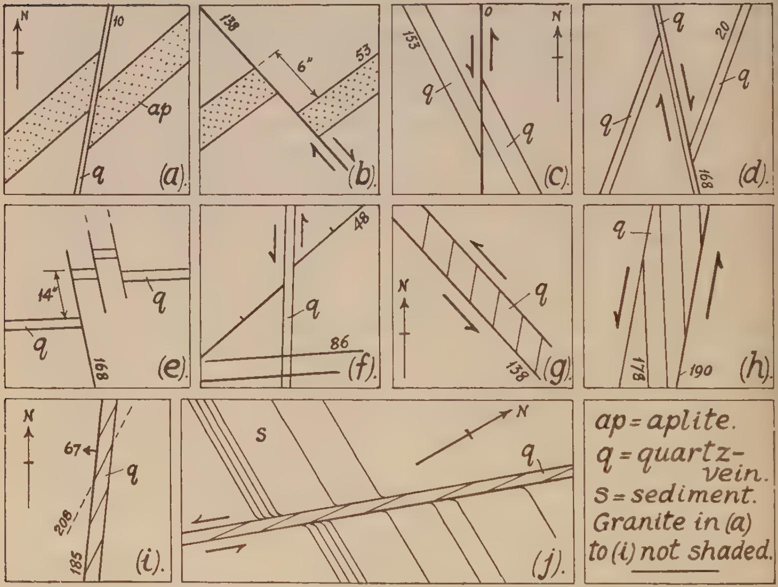


Fig. 8. Details of movements on joints and veins cutting granite. (For description, see text, pp. 241–2)

(a) *Fracture-cleavage* is illustrated in Fig. 8*g*, where a vertical 1-inch quartz-vein in the direction 138° is broken by steep, oblique fractures which do not extend beyond the walls of the vein: a left-handed movement is indicated. This example is one of a group of several veins having similar structures, and occurs in the belt of fractured granite at Mountain End described on p. 240 (Locality *C*). Other instances could be quoted, and also of aplite-veins showing fracture-cleavage. Sometimes a low-dipping quartz-vein shows fracture-cleavage, indicating a thrust movement. All these structures point to a later shearing movement along the line of an earlier fracture, after it had been filled with quartz or other material.

(b) *En échelon structures* (Reidel type) were observed in several exposures in the Mountain End area. One is illustrated in Fig. 8*h*, where oblique fractures at 178° lie across a wide, nearly vertical, quartz-vein whose walls run in the direction 190°. There is thus an acute angle of 12° between the walls and the *en échelon* fractures (which are contained within the vein), and a left-handed movement is indicated. At another locality, a 1-inch vein, which strikes at 185° and dips 67° west, has *en échelon* fractures in the direction 208° (Fig. 8*i*), giving an acute angle of 23° and showing a right-handed movement.

Occasional quartz-veins, which fill fractures in the hornfelsed sediments near the granite margin, also possess Reidel type shears, as shown in Fig. 8*j*. There is here the additional evidence of displaced vertical bedding planes to guide the interpretation. The vein illustrated was observed on Craig Hill, is vertical, and cuts vertical sediments nearly at right-angles. One band in the sediments shows a left-handed tear displacement of about six inches, with small drag effects; the *en échelon* shearing indicates a movement in the same sense. Two further deductions may fairly be made from this occurrence: first, that a *small* relative movement of the walls of a vein is sufficient to produce the *en échelon* fractures; second, that tear-faults affect the sediments adjacent to the granite in this area, as would be expected from general considerations.

The value of minor structures such as those described above is that they provide important clues as to the *sense* in which movements on fractures affecting the rocks have operated. Where many of these structures occur close together in a belt or zone at a particular place, they may point to the nearby presence of a larger fracture or fault, parallel to the minor ones. It is clear from the examples above, which could be greatly extended from many observations, that in the post-emplacement history of the granite (together with its aplites and early formed joints) there was a period of fracturing in which some fractures were filled with quartz; and a further episode, possibly pene-contemporaneous with the other, in which some quartz-veins were themselves severed by new fractures.

7. INTERPRETATION OF THE ORIENTATION DIAGRAMS

Of the four diagrams in Fig. 6, that relating to the directions of aplites and pegmatites, is dissimilar to the other three. It shows that the most frequent orientation of these vein-rocks is in the direction 100°, i.e., approximately parallel to oriented felspars in the granite when these are present (p. 232). The fractures correspond to longitudinal or *s*-joints (Balk, 1948, p. 34). The opening of these fractures, which became filled with aplite- or pegmatite-forming material, may thus be attributed to contraction of the granite pluton on cooling after emplacement, possibly together with upward pressure exerted by unsolidified material at depth against a solidified outer shell. Two subsidiary maxima in Fig. 6A, corresponding to fractures at 48° (vertical) and 150° (dip 85° west) respectively, may be expressions of groups of other open fractures formed in an early stage. Owing to the scanty data available they will not be further discussed.

In Figs. 6B, C, and D, a feature common to all three diagrams is the occurrence of two maxima at 72° and 89°, which have already been noted (p. 236); these correspond to vertical or nearly vertical joints and veins which run at 162° and 179° respectively, or approximately NNW. and SSE., and north–south, the two directions differing by 17°. In addition there are the subsidiary maxima at 198° and 176° which represent nearly vertical joints at 108° and 86°. These values are taken from the plot of joints and veins together (Fig. 6D); there are only small variations in the positions of the subsidiary maxima if they are measured on Figs. 6B or C.

Evidence for horizontal movements on veins and joints has been discussed earlier, and it is therefore a reasonable assumption to treat the joints as complementary pairs of shear fractures.

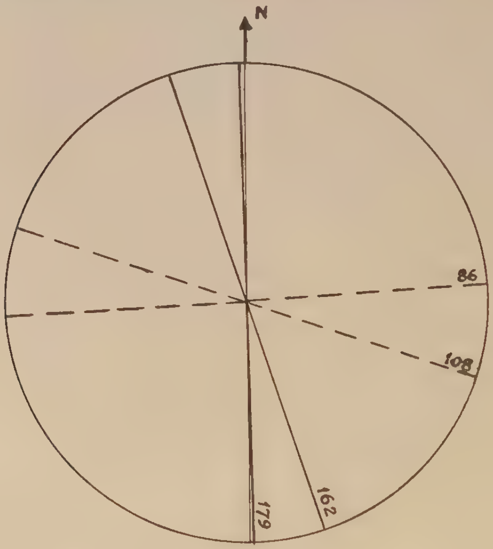


Fig. 9. Main joint directions in granite, Clints of Dromore

(i) One interpretation would be to take the 162° and 86° directions as a shear pair, with an acute angle of 76° between them (Fig. 9); the bisector of this angle is in the direction 124°, or roughly ESE. For the other pair, at 179° and 108°, the acute angle is 71° and the direction of its bisector 143½°, or not far from SE. Two onsets of compression, an earlier phase from WNW. to ESE., and a later phase approximately NW. to SE., would account for the formation of the two sets of fractures. The latter phase is considered the later of the two because it involves the 179° direction of shear, and, in the field, fractures having this trend are frequently seen to cut and displace others, including those in the 162° direction.

(ii) An alternative interpretation, which I prefer, takes into account the mode of fracturing which gives rise to *en échelon* shears making a small acute angle with the direction of the applied shearing force. This type of fracturing was described by Reidel (1929) in his discussion of experiments with clay in shear, and was used by the writer to explain certain structures in sheared dykes which outcrop in the country south of the Cairnsmore of Fleet granite (Blyth, 1949). It may be convenient here to give a résumé of the manner of formation of the fractures in the clay experiments, which I have repeated and observed in some detail. A fuller description is given in the paper just referred to (p. 413 and fig. 10).

In the experiments a slab of clay is placed on two boards, one of which can be made to move horizontally relative to the other, the edges of the boards remaining in contact. When relative movement occurs, shear is induced in a zone of deformation in the clay above the line of junction of the boards. Within this zone of deformation two sets of fractures develop: first a series of tension cracks, *en échelon*, which make an angle of about 45° with the direction of displacement; and second, a little later than the tension cracks, a series of shear-fractures, also *en échelon*, which make a small angle (up to about 20°) with the direction of displacement. By controlling the water-content of the clay the tension cracks can be suppressed and only the shear-fractures then appear. The kind of pattern made by the latter is shown in Fig. 8 (*h* and *j*). In my experiments the shear-fractures appeared after a small amount of deformation; if the shear-displacement is continued beyond this point, the whole zone of deformation eventually tears along one of its boundaries, which are parallel to the direction of displacement of the boards. Under these conditions, therefore, fractures formed in the clay are first the *en échelon* shears, and later the more severe shearing of the mass. The angle between the two directions of shearing is always small and generally not more than 20°.

Applying this result to the fractures in the Cairnsmore of Fleet granite margin, the sequence of events may have been as follows: After the granite was emplaced and had received its vein-injections of aplite and pegmatite along early formed fractures (due to contraction on cooling), the area became subject to tectonic stresses of external origin. Maximum shearing stresses developed in a zone which trended nearly north and south across the granite, affecting also the surrounding sedimentary rocks. One margin of the zone passed through Mountain End, the other probably along the (present) valley of the Big Water of Fleet. In this zone, relief was first obtained by slips along many parallel shear-surfaces in the 162° direction; these correspond to the *en échelon* shears in the experiments. A little later, with continued stress, the zone was torn along its margin—in the 179° direction—with the formation of horizontal fault-displacements. Quartz-veins in the two main shear-directions thus had a nearly contemporaneous origin, with the north–south series formed a little after those trending NNW.–SSE.[1] The complementary direction of shear was expressed in the nearly east–west joints.

This interpretation fits the main facts and accounts for the greater part of the field evidence. If it is correct we have here an illustration of the rupturing in shear of part of a large granite mass relatively soon after its solidification, and the filling of fractures in a belt of shearing by residual siliceous fluids which still remained within the granite at depth.

8. MODE OF EMPLACEMENT AND AGE

Several facts point to the conclusion that the Cairnsmore of Fleet granite was intruded as a magmatic body, and for the area investigated the present ground surface corresponds to what was, at the time of emplacement, a relatively high level in the earth's crust. The evidence includes:

(i) The presence of a marginal zone containing many xenoliths and rafts or tabular inclusions of sediment.
(ii) The presence of an aureole of contact metamorphism.
(iii) The general lack of evidence of metasomatism in the aureole rocks, and the sharp outlines of included country-rock.
(iv) The similarity in composition of samples of granite taken at intervals along its southern margin (p. 227). Differing proportions of biotite and muscovite in the rocks, and the common occurrence of biotite-granite adjacent to the contact, may be explained in terms of reaction between the magma and its walls, including perhaps limited assimilation of country-rock.

Various indications that the temperature of intrusion was relatively low have been noted in the foregoing pages, and these would agree with other evidence in suggesting that the granite belongs to the group of high-level plutons defined by Read (1949, p. 149), emplaced late in the closing stages of an orogenic episode. The source of the granite magma may have been relatively distant, and its origin is at present conjectural.[2]

From the nearly vertical southern contact (Fig. 10), and from the parallelism between the contact and the strike of the vertical sediments, emplacement of the granite here probably involved mainly upward movement of magma along a series of dyke-like channels, the tops of which perhaps became united into a single mass. Upward displacement of the roof-rocks of such dyke-like bodies, in response to magmatic pressure, would have been facilitated by the verticality of the bedding-planes of the closely folded sediments; the latter were sheared and moved upwards by the pressure.

---

[1] Several degrees of deviation on either side of the mean directions quoted are allowable, especially in view of the fact that the rocks of the area were not homogeneous, but consisted of granite (itself a complex body) and isoclinally folded sediments. The values 162° and 179°, obtained by a statistical analysis, are used in the above discussion in order to present the essential conception as clearly as possible.

[2] While it is not desirable to make generalisations about the whole granite from data obtained from one part of it, the above conclusions are put forward tentatively on the facts available. They are supported by information gained from traverses made by the author into the granite area, and from a study (still in progress) of the northern and western margins.

The last, mainly vertical, fault-movements, which were responsible for *local* uplift of the granite margin along the line of the Clints, may have been due to internal pressure gaining relief along the faults which were already in existence, giving small vertical components on those faults. This part of the granite margin was able to yield because of its already fractured condition.

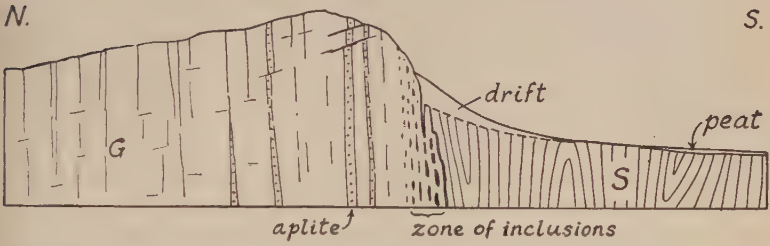


Fig. 10. Diagrammatic section across the Clints of Dromore. G=granite; S=sediments

The age generally assigned to the Southern Upland granites is late Caledonian (Lower Old Red Sandstone), since they invade the already folded Ordovician and Silurian sediments. Upper Old Red Sandstone rests unconformably on one of the smaller granites at Cockburn Law, ten miles SW. of St. Abbs' Head, Berwickshire (Geikie, 1897, pp. 290, 340), and from this it has presumably been inferred that the whole group of granitic masses dates from Lower Old Red Sandstone times. During Middle Old Red Sandstone times a renewal of orogenic activity occurred (the Sval-Bardic phase of Wills, 1951), and the development of the fractures discussed in this paper may date from that period.

The Lower Old Red age of the porphyrite dykes, which are found in the adjacent South Galloway area, has been discussed elsewhere (Blyth, 1949, p. 395), and their shearing has been ascribed to the Middle Old Red phase of the Caledonian orogeny, during which an ESE. to WNW. compression probably affected the area. The opinion was expressed that this episode must have involved a wide region. The fracturing of the granite discussed in the present paper was probably another expression of that episode, because both in timing and in the direction of compression it agrees with the evidence of the sheared porphyrite dykes.

9. SUMMARY OF CONCLUSIONS

Along the southern margin of the Cairnsmore of Fleet granite, the prominent topographical feature formed by the Clints of Dromore is due to the presence of a zone of tear-faulting, which crosses the granite margin there in a nearly north and south direction. Faults can be traced north towards Loch Grennoch. After the emplacement of the granite in the closely folded sediments of the area, probably in Lower Old Red Sandstone times, the faults were formed during a succeeding phase of the Caledonian orogeny, when compression operated approximately from ESE. to WNW. A little later, vertical movements on the north–south fault system (perhaps due to internal pressure within the pluton) uplifted the granite along the line of the Clints, the series of crags being revealed by subsequent denudation. Hollows were eventually scoured out by the Pleistocene ice along the lines of fracturing in the granite. The Big Water of Fleet, where it crosses the granite margin, probably follows a fault.

An analysis of the joint-system in the granite along its southern margin shows that prominent sets of joints are parallel to faults, and are therefore probably of tectonic origin. Numerous quartz-veins, mainly vertical, also occur in parallel groups near to major faults; other less regular veins are also present. Structural details within the veins, such as *en échelon* shearing, indicate directions of relative movement of their walls and, by inference, of the major fractures to which they are parallel. There is evidence of left-handed movement at Mountain End. Preferred orientations of joints and veins are demonstrated by stereographic diagrams.

Many aplites and pegmatites fill early-formed fractures in the granite; a large proportion of these vein-rocks lies parallel to the direction of orientation of the scanty porphyritic felspars which are seen in a few places near the granite boundary.

A narrow marginal zone of the granite contains inclusions of hornfelsed sediments, most of which lie with their flat surfaces parallel to the nearly vertical bedding-planes of the rocks next to the contact, though others are disoriented. Evidence of metasomatism is lacking, and it is concluded that the granite of the area studied was emplaced as magma, perhaps rising along approximately vertical channels. Soon after its solidification, but before it had completely cooled, it was fractured in the manner described above, and the fractures filled with residual siliceous fluids. Several indications point to a relatively low temperature of intrusion, but the inference awaits confirmation from future research on the whole granite mass.

EXPLANATION OF PLATES 5 AND 6

Plate 5. A. Central part of the Clints of Dromore, looking NNE. towards the Deep Nick across a peaty flat. The lower slopes of the ridge on the west (left) are masked by drift.

B. Eastern end of the Clints of Dromore, showing breaks in the line of the crags due to faulting (1st and 2nd 'nicks' on right) and the prominent north–south joints emphasised by shadow.

Plate 6. A. Map of the granite boundary at the Clints of Dromore. Localities *A* to *E* are referred to in the text. *G* = vein of granite.

B. Details of rocks exposed at railway cutting near Dromore, on north side of line. Granite boundary shown by broken line; exposures of sedimentary rocks are shaded.

REFERENCES

BALK, R. 1937. Structural behaviour of igneous rocks. *Mem. Geol. Soc. Amer.* 5. (Reprinted 1948).

BLYTH, F. G. H. 1949. The sheared porphyrite dykes of South Galloway. *Quart. Journ. Geol. Soc. Lond.*, **105**, 393.

GARDINER, C. I. & S. H. REYNOLDS. 1937. The Cairnsmore of Fleet Granite and its metamorphic aureole. *Geol. Mag.*, London, **74**, 289.

GEIKIE, SIR A. 1897. *Ancient volcanoes of Great Britain.* **1.**

HORNE, J. 1896. *Mem. Geol. Surv. Scot.* (*Sheet* 5), Kirkcudbrightshire.

IRVINE, D. R. 1878. *Mem. Geol. Surv. Scot.* (*Sheet* 4), E. Wigtownshire.

PRINGLE, J. 1935. British regional geology: The South of Scotland. *Mem. Geol. Surv.* (2nd Ed. 1948).

READ, H. H. 1949. A contemplation of time in plutonism. *Quart. Journ. Geol. Soc. Lond.*, **105**, 101.

REIDEL, W. 1929. Zur Mechanik geologischer Bruchescheinungen. *Centralb. f. Min. Geol. u. Pal.*, 1929, B, 354.

SHAND, S. J. 1949. Eruptive Rocks (4th edition). London.

TEALL, J. J. H. 1899. *In* The Silurian Rocks of Britain, **1**: Scotland. *Mem. Geol. Surv.*

WILLS, L. J. 1951. *Palaeogeographical Atlas.* London.

DISCUSSION

DR. J. SUTTON congratulated the author on an extremely interesting paper which threw further light on the way in which the structures near a single granite mass are related to the regional tectonics.

He asked whether structures similar to those found on the south margin were to be found elsewhere, and in particular on the east or west sides of the igneous mass? He further wished to know if the author had been able to establish whether the granite had at any time contracted during its formation. The tight folds with quartz-nodes, which had been described, were reminiscent of those found round the Ardara mass in Donegal, where Mr. Akaad is at present working, and presumably in each instance indicated an outward expanding motion of the igneous rock. Yet many granites, particularly those in which early joints control the shape of later phases, might well have contracted during their formation. Was there any sign of contraction in this instance? Could the marginal overthrusting be interpreted as underthrusting due to the contraction of cooling lower part of the mass past the already solid upper part? And could the room for the late veins, which made up eight to ten per cent of the rock in some localities, have been provided through the contraction of the granite host?

It would be interesting to know how the composition of the alkali felspars varied in view of the recent work of Bowen, Chayes and Tuttle on this question.

DR. A. T. DOLLAR congratulated the author on his lucid presentation of a detailed structural study of a granite contact. It raised a number of interesting questions.

First, regarding the prominent group of nearly vertical granite joints of dominantly north–south strike which the author ascribed to a tectonic origin, the speaker asked whether it was not possible that, in view of their orientation with respect to the contact, they were *contractional*, initially, but that certain of them became faulted later?

Next, from the lantern slides of photographs of the crags, and of stereographic joint-orientation diagrams derived from a study of the latter, it seemed to Dr. Dollar that sub-horizontal joints—the so-called 'bedding' joints, 'lager', or L-joints of H. Cloos—were poorly represented in them, if at all. He asked whether this kind of evidence for the former proximity of a *roof* over the granite was, in fact, largely or entirely absent, as distinct from the full assemblage of *wall*-phenomena which Dr. Blyth had described, or was it that the particular photographs concerned did not show these planes, and the author had not represented them on his stereograms for analytical reasons? Were these joints present in the main mass of the granite, north of the Clints?

Finally, in connection with evidences of volatiles associated with the parent fluids of the aplites and pegmatites, Dr. Dollar inquired as to whether Dr. Blyth had found druses in either or both of these rock-types, and if so, what was their distribution?

DR. W. S. PITCHER asked whether the minor structures were more intimately connected with the late stages of granite emplacement than had been suggested by the author.

DR. E. H. T. WHITTEN referred to the penultimate slide exhibited by Dr. Blyth, which showed (in vertical section) relics of country rock incorporated within the granite. The illustration indicated that these xenoliths retained their original position though totally enclosed by the magma. The speaker asked whether this was indeed a small-scale case of 'ghost stratigraphy', and whether the diagram must be taken literally so as to imply that despite the proved fluxion of the granite, the xenoliths had not been rotated or moved at all.

DR. BLYTH, in reply to Dr. Sutton, said that he had observed sets of vertical joints with a northerly trend at a number of localities in the wider area of the granite; they were found, for example, near the northern margin of the granite at Clatteringshaws. This northerly direction of jointing seemed to be a dominant one. As to whether the aplite veins represented the filling of contraction joints, or whether they indicated expansion in the upper part of the pluton, Dr. Blyth thought that the aggregate width of the veins at some localities was too great to be accounted for solely by contraction. Doubtless contraction joints had developed in the granite during the early stages of cooling, and these were filled with aplite, but some were opened out further by the pressure of incoming material.

The exact nature of the alkali felspars in the granite had not been determined on more than one or two samples; but all the rocks examined in thin sections contained microcline or microcline-perthite, and a plagioclase (about oligoclase).

Dr. Dollar also inquired about joints: the author considered the nearly north–south sets to be of tectonic origin, as they affected rocks farther afield than the immediate area under discussion, and for other reasons given in the paper. Flat-lying sheet-jointing, as commonly found in many granites, was not apparent in the area under consideration (unless vertical east–west joints, parallel to the vertical contact, could be regarded as sheet-jointing in this instance). No large druses in aplites or pegmatites had been observed, though small cavities, and patches of locally coarser texture in aplites, were often present.

In reply to Dr. Pitcher, the author considered that while the many movements on veins, which he had described, had probably occurred not long after the emplacement of the granite, yet the latter was rigid enough to have fractured when the veins and joints were formed.

Dr. Whitten referred to the generalised cross-section of the contact (Fig. 10 of the paper) and asked if the preservation of many xenoliths in original positions was an example of 'ghost stratigraphy': in the paper it was pointed out that many hornfels enclosures in the granite had been turned out of alignment, and not all were vertical; the country rocks were predominantly grits, and the lack of suitable marker horizons would make it difficult to assess the presence or absence of a 'ghost stratigraphy'. In any event, 'ghost stratigraphy' as normally understood was not to be expected in a high-level pluton such as this.

A Temporary Exposure in the Bracklesham Beds near Sopley, Hampshire

by P. E. FAIRBAIRN

Received 31 August 1953

CONTENTS

1. INTRODUCTION ... page 251
2. THE SOPLEY SECTION ... 251
3. STRUCTURE ... 254
4. STRATIGRAPHICAL HORIZON ... 254
REFERENCES ... 254

SUMMARY: Excavation for engineering works near Sopley, Hampshire, with four exploratory boreholes, has proved over 90 ft. of Bracklesham sands and clays under terrace gravels of the River Avon. A detailed description of these beds is given, and their probable correlation with the Bournemouth–Highcliffe coast-section discussed.

---

1. INTRODUCTION

NO ATTENTION appears to have been paid to the Bracklesham Beds of the Bournemouth–Christchurch area since the publication of the Geological Survey Memoir on the Bournemouth area (White, 1917). Comment was made in that work on the difficulty of inland mapping caused by the paucity and weathered condition of exposures. At the northern end of St. Catherine's Hill, 2½ miles NNW. of Christchurch, Gardner (1879) mapped 3 ft. of probable Highcliffe Sands overlying 13 ft. 6 in. of Hengistbury Beds, and suggested that 'the valley of the Avon on the east is probably scooped out of the yielding Highcliff Sands'. The 1917 memoir accepts this conclusion, though it points out that 100 ft. of 'yellow sands with some intercalations of grey sandy clay' can be identified above Gardner's section, and that if these belong to the Highcliffe Sands, the thickness of that division here is at least double that on the coast, five miles away. Outcrops of sandy beds between Bransgore and Woodend, two miles east of the River Avon, are ascribed by the Survey to the Highcliffe Sands.

2. THE SOPLEY SECTION

The village of Sopley is situated 2½ miles north of Christchurch, on the east bank of the River Avon. The beds to be described were exposed in four boreholes put down to a depth of 90 ft. (in one case 105 ft.) on a site approximately half a mile NNE. of the village, to test the suitability of the ground for engineering construction. These four boreholes were located approximately at the corners of a north–south rectangle, 290 ft. × 250 ft., the normal national grid reference of the north-east borehole being 162.978. The top 50 ft. of the ground traversed by the boreholes were subsequently opened up in excavation, and an opportunity was afforded of studying depositional characteristics of the beds which boring had failed to reveal.

The beds are capped by a thickness varying from 12 to 23 ft. of terrace-gravels of the River Avon. These consist of red-brown sandy flint gravels in which sizing analyses show approximately 80% in the gravel fraction (+2 mm.) and pebbles ranging up to two inches. They occur in an area assigned by J. F. N. Green (1936 and 1946) to the Muscliff Terrace of the Avon–Stour river-system, and have been laid down upon a gently undulating surface of Bracklesham Beds. Much leaching and redeposition of iron has taken place at and immediately below the base of the gravels, giving rise to local secondary phenomena such as colour-banding cutting steeply across the stratification, and cementation of the Bracklesham sands to form a highly ferruginous sandstone.

The Bracklesham Beds consist of highly compacted medium- to fine-grained light- to dark-grey or liver-coloured current-bedded lignitiferous sands with minor horizons of chocolate-brown clay associated with impersistent thin seams of lignite and fragments of fossil wood. The sands show well-marked segregation into medium- and fine-grained streaks and tend to become lighter-coloured with depth. The current-bedding is picked out, particularly towards the bottom of the sequence, by impersistent wisps and streaks of black lignitic material. This material also occurs as small cylindrical masses an inch or two in diameter which presumably represent original drifted plants.

The following is a generalised sequence through the series, compiled from a series of sections down the sides of the excavation with details of the bottom 55 ft. added from borehole information:

		ft.	in.
Fine sand, locally ironstained	+	2	0
Lignite and clay		0	3
Fine white to light grey sand		2	0
Lignite and clay		0	8
Coarse white sand		1	0
Medium- to dark-grey fine lignitiferous sands		7	0
Fine medium grey-brown sands		5	0
Fine chocolate-brown clay with local impersistent lignite seams and beds of fine sand		1	0
Fine light grey-brown lignitiferous sands		3	6
Clay-lignite seam (local only)		0	2

	ft.	in.
Fine- to medium- and coarse-grained white to light-greyish-brown lignitiferous sands, becoming whiter, and showing well-marked differentiation into fine- and medium-grained bands; local thin impersistent layers of soft black silty clay	60	0
Chocolate-brown silty clay locally interbanded with thin layers of fine- to medium sand	14	6
Fine-, medium- and coarse-grained lignitiferous sand ... +	3	6
	100	7

The writer would emphasise that the above sequence is generalised and that thicknesses are average figures only. Colour and grain-size vary rapidly in the sands, laterally as well as vertically, while lignite and clay seams are impersistent and lenticular.

For purposes of the site investigation a number of laboratory tests were carried out on the sands, and these may be briefly summarised. Particle size curves show that the grain-size of individual samples is remarkably uniform. Out of 13 curves the maximum fraction exceeding 0.6 mm. (the boundary between medium and coarse sand) was 6%, and in no other instance did this figure exceed 3%. At the other end of the scale, the maximum fraction passing a 200-mesh sieve (rather less than 0.08 mm. and comparable with the boundary between fine sand and coarse silt of 0.06 mm.) was 3%. Within this narrow range, moreover, the curves are extremely steep, pointing to a high degree of water sorting such as might be expected from material which has been worked and reworked by cross-currents under estuarine conditions.

Tests *in situ* give the average natural dry density of the sands as 106 lb./cu. ft., which is high for uncemented sand and approximates to the figure for 'maximum' dry density obtained by compaction of the loose material in the laboratory. 'Minimum' dry density is about 90 lb./cu. ft. A detailed description of these tests has been given in a recent paper by Nixon (1954).

Horizons of scattered rounded flint pebbles up to two inches in diameter occur at intervals throughout the sands. These pebbles show varying degrees of desilicification, and are composed of material ranging from dark-grey almost unaltered flint to a soft friable white chalk-like substance which can easily be broken in the fingers. The more decomposed specimens bear a close resemblance to those recently described from the Headon Beds of Brockenhurst (Davies, 1952), and to the well-known Blackheath Pebble Beds of Knockmill, Kent (Chandler & Leach, 1936). Little appears to be known about the process which has given rise to material of this nature, or of the reason why pebbles should be selectively attacked. Electron-micrographs of the material have been taken, and the writer hopes that the results from these, together with certain other laboratory tests, will form the subject of a subsequent paper.

3. STRUCTURE

Owing to the impersistency of individual bands and the widespread development of current-bedding, it has been impossible to determine the dip and strike of the series with any degree of precision. Mapping in the excavation leads to the impression that the beds are near-horizontal or gently undulating.

Three of the four exploratory boreholes intersected the top of the 14 ft. 6 in. clayey band just above the base of the series. This band was, however, not encountered in the fourth borehole, and there is no means of deciding whether its absence is due to lensing out or to a local fold putting it below the bottom of the borehole. Boring cannot be said to have yielded any structural evidence additional to that obtained from surface mapping.

4. STRATIGRAPHICAL HORIZON

Burton (1933) records Lower Barton Beds below gravels near Bransgore Post Office, at a brickyard about one mile east of the Sopley excavation. No nearer exposures of Eocene Beds are known. The position in the stratigraphical column of the 100 ft. of beds proved at Sopley is therefore a problem of considerable interest.

Palaeontological evidence is unfortunately lacking. Apart from the local presence of unidentifiable fossil wood, the sands and clays are entirely unfossiliferous, and washing of a number of the more clayey samples failed to yield any microfauna. The only guide to correlation with the coast section over four miles away to the south is the lithological character of the beds.

Examination of the cliffs stretching east of Bournemouth to Southbourne and Hengistbury Head shows that the division of the Bracklesham Beds most closely resembling the Sopley section is the Bournemouth Marine Beds. Where exposed in the cliffs between Bournemouth and Honeycomb Chine, these consist of white to light- and dark-grey lignitic sands with chocolate- and liver-coloured clays. They are described in detail by White (1917, pp. 29–33). In the absence of further evidence their correlation with the Sopley Beds seems reasonable. The Bagshot–Bracklesham boundary in this area is highly dubious (White, 1917, pp. 19–20), and the possibility that lower members of the Sopley series may be of Bagshot age cannot be disregarded.

The author wishes to express his thanks to Messrs. Soil Mechanics Ltd., who afforded facilities for the above study, and to Messrs. Mott, Hay & Anderson, Consulting Engineers, for permission to publish the results.

REFERENCES

Burton, E. St. John. 1933. Faunal horizons of the Barton Beds in Hampshire. *Proc. Geol. Assoc.*, **44**, 131–67.

CHANDLER, R. H. & A. L. LEACH. 1936. The structure of the Eocene Outlier near Knockmill, Kent. *Proc. Geol. Assoc.*, **47**, 239–48.

DAVIS, A. G. 1952. The Brockenhurst Beds at Victoria Tilery, Brockenhurst, Hampshire. *Proc. Geol. Assoc.*, **63**, 215–19.

GARDNER, J. S. 1879. Description and correlation of the Bournemouth Beds. Part I. Upper Marine Series. *Quart. Journ. Geol. Soc. Lond.*, **35**, 209–28.

———. 1882. Description and correlation of the Bournemouth Beds. Part II. Lower or Freshwater Series. *Quart. Journ. Geol. Soc. Lond.*, **38**, 1–15.

GREEN, J. F. N. 1936. The Terraces of Southernmost England. *Quart. Journ. Geol. Soc. Lond.*, **92**, lviii–lxxxviii.

———. 1946. The Terraces of Bournemouth, Hants. *Proc. Geol. Assoc.*, **57**, 82–101.

NIXON, I. K. 1954. Some investigations on granular soils, with particular reference to a compressed-air sand sampler. *Géotechnique*, **4**, No. 1, 16–30.

REID, CLEMENT. 1898. The geology of the country around Bournemouth. *Mem. Geol. Surv.*

WHITE, H. J. OSBORNE. 1917. The geology of the country around Bournemouth. *Mem. Geol. Surv.*, 2nd Ed.

Loessic Deposits in the Fifty-foot Terrace post-dating the Main Coombe Rock of Baker's Hole, Northfleet, Kent

by J. P. T. BURCHELL

Received 29 October 1953

THE PURPOSE of this account is to put on record the evidence obtained from a series of brickearth deposits located between Erith and Swalecliffe, in Kent, and nowhere attaining a height of more than 40 ft. above O.D.

These brickearths all post-date the glaciation responsible for the formation of the Main Coombe Rock of Baker's Hole, Northfleet, Kent, and would appear to ante-date the deposition of the *Corbicula fluminalis* Bed of Taplow Terrace No. 2 as evidenced in the Crayford–Erith district.

The brickearths under consideration are characterised by the presence in them of a specific molluscan fauna markedly restricted in the number of types it contains.

Further, the predominating occurrence of the three species—*Pupilla muscorum* (Linn.), *Vallonia costata* (Müll.) and *Succinea oblonga* (Drap.)—indicates that the brickearths which contain them were accumulated under climatic conditions which favoured the formation of loess.

Section No. 1. *Rutter's Pit East.* Rutter's Pits East and West are situated midway along and on opposite sides of the road running south to north from Crayford to Erith (Kennard, 1944, p. 123). The deposits in the latter pit has been described by R. H. Chandler; and the artifacts he discovered at the base of the Lower Brickearth have been duly illustrated and commented upon (Chandler, 1916). The same geological sequence obtains in Rutter's Pit East, which has ceased to be a Recreation Ground and is now a Municipal rubbish dump.

Immediately east of the road the *Corbicula fluminalis* Bed, located between the Upper and Lower Brickearths, used to be well exposed.

Temporary excavations conducted since the recent war in the eastern margin of this former pit showed the following typical section:

	ft.	in.
Trail which has ploughed into and largely removed the Upper Brickearth	5	0

	ft.	in.
Bed of sand—with thick layer of 'race' at base—representing the decalcified *Corbicula fluminalis* (Müll.) horizon	2	0
Lower Brickearth:		
c. upper part, sandy	9	0
b. middle part, slightly clayey		
a. lower part, sandy		
Fine current-bedded gravel with large flints at base resting on Chalk	14	0

Material from the upper and middle parts of the Lower Brickearth has yielded 65 and 54 specimens of *Pupilla muscorum* respectively, whereas no shells were recovered from the lower part of this brickearth.

Section No. 2. *Greenhithe Valley*. Four and a half miles to the east of Section No. 1 and situated in the east face of the tramway-cutting immediately east of Stone Castle the following section is exposed:

	ft.	in.
Loam with occasional thin seams of very small flint pebbles	1	0
Sandy brickearth	6	6
Fine gravel resting on Coombe Rock capping Chalk	1	3

Towards the base of the sandy brickearth the deposit yielded the following molluscan fauna:

Pupilla muscorum (Linn.)	152
Vallonia costata (Müll.)	18
Succinea oblonga (Drap.)	3
Limax sp.	1

Section No. 3. *Ingress Vale*. Half a mile east of Section No. 2 and situated in the north face of the tramway-cutting immediately to the north of the railway line, which crosses the end of the valley, the following section may be examined:

	ft.	in.
Surface soil	1	0
Hillwash	3	0
Decalcified stoneless loam	3	0
Layer of chalk pebbles	0	3
Stoneless sandy brickearth with very small chalk pellets	2	6
Coarse unstratified gravel resting on Coombe Rock overlying Chalk		

Examination has shown that the stoneless, calcareous and sandy brickearth contains a molluscan fauna.

The upper part of the deposit yielded:

Pupilla muscorum (Linn.)	39
Vallonia costata (Müll.)	104
Limax sp.	1

whereas the lower part contained a molluscan fauna restricted both in types and numbers—viz:

Pupilla muscorum (Linn.)	30
Limax sp.	1

Section No. 4. *Ebbsfleet Channel.* One and a half miles east of Section No. 3 is to be found a lateral valley which formerly drained eastward into the Ebbsfleet.

The sequence of the deposits comprising the infilling of this channel which has been cut through the Main Coombe Rock into the underlying Chalk has already been described (Zeuner, 1945, pp. 127–30; 1952, pp. 193–4, 439–40).

For the purpose of this account it is only necessary to refer to the Middle Loam and its overlying bed—the Upper or Temperate Loam.

The Middle Loam is a slightly clayey, sandy brickearth divided into two parts by a seam of Coombe Rock. The surface of the upper part of this brickearth is weathered.

The upper part of the Middle Loam has yielded:

Pupilla muscorum (Linn.)	45

whereas the lower part proved richer in its molluscan content as is shown hereunder:

Pupilla muscorum (Linn.)	103
Vallonia costata (Müll.)	36
Limax sp.	4

Thin lenticles of loam incorporated in the Coombe Rock which divides the Middle Loam into two parts have been found to contain the following shells:

Pupilla muscorum (Linn.)	25
Vallonia costata (Müll.)	6

The Upper Loam, or Temperate Bed, which overlies the Middle Loam, offers a marked contrast in the number of species of shells which were living at the time of its deposition, and at the same time reflects in its upper part the renewed oncoming of less congenial climatic conditions culminating in the formation of another Coombe Rock.

The lower part of the Upper Loam has yielded 27 species of shells whilst the upper part of this loam has produced but 12 molluscan species. A thin layer of highly calcareous loam which rests on the Temperate Bed and immediately underlies Coombe Rock shows a progressive decline in the number of molluscan species—only six having been recovered from this deposit.

The value of the Ebbsfleet sequence is greatly increased by virtue of the archaeological evidence it affords. For in the gravel underlying the Lower Loam there occurs a Middle Levalloisian industry; whilst the Upper Loam, or Temperate Bed, which overlies the Middle Loam, contains a Micoquian culture.

Section No. 5. *Swalecliffe.* Moving 33 miles eastwards from Section No. 4 the remains of a lateral valley may be observed which formerly drained northwards into the Thames.

The section was first noted by J. Prestwich (1861, pp. 365–6) but it was not until F. H. Worsfold studied in detail the length of section along the foreshore that the importance of the deposits became apparent. Worsfold (1926 *a*, *b*), however, ignored the opportunity of establishing the molluscan distribution.

The channel, cut through Pleistocene deposits into the underlying London Clay, is some 600 ft. wide. Today, only the western portion of the channel may be observed. The deposits, which compose its infilling, may, in descending order, be summarised as follows:

5. Trail or solifluxion deposit
4. Upper Brickearth
3. Shell Bed
2. Lower Brickearth
1. Gravel

The total height of the section is about 14 ft. above the level of the foreshore. Some 180 ft. east of the western flank of the channel the Shell Bed, Lower Brickearth and Gravel all dip below the level of the foreshore. For the first few feet eastwards from the western flank of the channel the Shell Bed has suffered decalcification to such an extent that its molluscan content has been destroyed.

Immediately east of this decalcified area shells are present in large numbers—some 180 specimens to 2 lb. of matrix—and comprise the following species:

Pupilla muscorum (Linn.)	339
Limax spp.	15
Arion granules (small; not counted).	

Twenty-five feet eastwards the Shell Bed yielded the following shells:

Pupilla muscorum (Linn.)	386
Trochulus hispidus (Linn.)	4
Limax spp.	36
Arion granules (small; not counted)	

Midway between the western flank of the channel and the point at which the Shell Bed passes below the level of the foreshore, a marked change is introduced in the composition of the molluscan fauna, viz:

Pupilla muscorum (Linn.)	311
Succinea oblonga (Drap.)	70
Limax spp.	10
Arion granules (small; not counted)	

Three-quarters of the distance from the western flank of the channel to the spot where the Shell Bed disappears below the shore-line the number of shells in a 2 lb. sample of matrix has fallen to about 30. The following shells were obtained at this point:

Pupilla muscorum (Linn.)	346
Succinea oblonga (Drap.)	102
Limax sp.	—
Arion granules (small; not counted)	

A foot or so to the west of where the Shell Bed dips below the level of the shore the undermentioned species occurred:

Pupilla muscorum (Linn.)	220
Succinea oblonga (Drap.)	329
Limax spp.	8
Arion granules (small; not counted)	

The molluscan distribution across this channel at the time of the accumulation of the Shell Bed matrix shows that, at the flanks of the channel, dry conditions obtained which gave way progressively to the centre of the channel to a state of affairs where the loess contained sufficient moisture to allow *Succinea oblonga* to flourish.

Section No. 6. *Snodland.* Dropping nine miles south-eastwards from Section No. 4, the following sequence of deposits is exposed at the entrance to the Holborough Chalk Pit:

	ft.	in.
Sub-aerial loam No. 3 of the younger series	7	0
Sub-aeriel loam No. 2 of the younger series	0	4
Layer of chalk pebbles set in a calcareous matrix	1	3
Stoneless sandy brickearth with chalk pellets	2	3
Coombe Rock resting on Chalk.		

A preliminary examination of the section has shown that the sandy brickearth, which is the only deposit in the succession material to this account, yields, in limited numbers, the following shells:

Pupilla muscorum (Linn.)	4
Vallonia costata (Müll.)	10

This molluscan fauna is very local in the deposit.

The molluscan evidence obtained from the sections described above would appear to establish a period of loess formation between the time of the occupation of the Middle Levalloisian 'floors' of the Crayford–Erith area and of the Ebbsfleet Channel, Northfleet, and that of the reintroduction of temperate conditions reflected by the *Corbicula fluminalis* Bed of the Crayford–Erith district and the Temperate Bed of the Ebbsfleet Channel.

In conclusion I express my gratitude to B. W. Sparks of Cambridge University and to the late A. S. Kennard for having determined the shells which form the subject of this summary and are now housed in the British Museum (Natural History).

REFERENCES

CHANDLER, R. H. 1916. The implements and cores of Crayford. *Proc. Preh. Soc. E. Anglia*, London, **2**, 240–8.

KENNARD, A. S. 1944. The Crayford Brickearths. *Proc. Geol. Assoc.*, **55**, 121–69.

PRESTWICH, J. 1861. Notes on some further discoveries of flint implements in beds of post-Pliocene gravel and clay; with a few suggestions for search elsewhere. *Quart. Journ. Geol. Soc. Lond.*, **18**, 362–8.

WORSFOLD, F. H. 1926*a*. An examination of the contents of the brick-earths and gravels of Tankerton Bay, Swalecliffe, Kent. *Proc. Geol. Assoc.*, **37**, 326–39.

———. 1926*b*. Observations on the provenance of the Thames Valley pick, Swalecliffe, Kent. *Proc. Preh. Soc. E. Anglia*, London, **5**, 224–31.

ZEUNER, F. E. 1945. The Pleistocene Period. *Ray Society*, London.

———. 1952. *Dating the past. An introduction to Geochronology*. London, 3rd Ed.

Falciferella, a new genus of Gault Ammonites, with a review of the family Aconeceratidae in the British Cretaceous

by R. CASEY

Published by permission of the Director of the Geological Survey of Great Britain

Received 9 March 1954

CONTENTS

1. INTRODUCTION ... ... *page* 262
2. STRATIGRAPHICAL AND FIELD OCCURRENCES OF *FALCIFERELLA* 263
3. MORPHOLOGICAL FEATURES, SYSTEMATIC POSITION AND DISTRIBUTION OF THE ACONECERATIDAE 267
4. SYSTEMATIC ACCOUNT OF BRITISH ACONECERATIDAE 269
EXPLANATION OF PLATE 276
LIST OF REFERENCES 276

ABSTRACT: The miniature ammonite *Falciferella milbournei*, gen. et sp. nov. (pp. 273–6), is described from the Lower Gault of Kent, south-east England. It is a common fossil in the upper part of the Middle Albian *Hoplites dentatus* Zone (*Anahoplites intermedius* Subzone), though by some extraordinary oversight its presence has hitherto escaped notice.

Falciferella is a 'cryptogenetic' genus whose nearest known allies are in the Aconeceratidae, a family of controversial affinities, here regarded as a relic of the great Jurassic superfamily Oppeliacea. The few records of this family from the British Cretaceous are further increased by the recognition of *Sanmartinoceras* (*Theganeceras*) in the Aptian of Lincolnshire and of species of the group of '*Oppelia*' *patagoniensis* Favre in the Hauterivian Speeton Clay of Yorkshire. For this latter group the new nominal genus *Protaconeceras* (p. 269) is proposed.

The morphological features, systematic position and distribution of the Aconeceratidae are briefly reviewed.

---

1. INTRODUCTION

DURING THE PAST few years Mr. R. A. Milbourne of Bromley has been engaged in fossil-collecting from various Gault exposures in north Kent and from time to time has submitted to me for determination the ammonites found in the course of his work. In September 1953 he sent me a small suite of specimens from the Sevenoaks Brick Company's pit at Greatness Lane, Sevenoaks. Among them was a crushed fragment impossible to place in any genus hitherto known from the Gault and seemingly allied to the typically Aptian family Aconeceratidae. Considering that no representatives of the Aconeceratidae are described in Dr. Spath's *Monograph of the Ammonoidea of the Gault*, and that from the whole of the British Cretaceous there are only a few scattered records of the family, the occurrence called for immediate investigation. Subsequent visits to the Greatness pit, to the neighbouring exposure at Dunton Green and a re-examination of the type-section of the Gault at Folkestone, led to the discovery that this ammonite, described below as *Falciferella milbournei*, is a fairly common fossil in the *Anahoplites intermedius* Subzone, and that on certain horizons within that subzone it is quite abundant. Unlike such genera as *Engonoceras*, *Gastroplites* and *Uhligella*, which are represented in the Gault of south-east England by rare stragglers or drifted shells, *Falciferella* is an autochthonous genus which for a short time flourished side-by-side with the prolific hoplitid fauna of the English Middle Albian. That its presence has only now been detected seems incredible. The Gault has long been renowned as a happy hunting-ground for the fossil collector and at Folkestone the faunal content of its various beds has been the subject of methodical study by generations of workers; while the pits at Dunton Green and Sevenoaks form part of the education of nearly every London student of geology. The reason for this ammonite having been overlooked in the past is probably that it is a small form, usually not much larger than a farthing, and at a casual glance is easily mistaken for the nucleus of the common *Anahoplites planus* (Mantell) of the same bed.

Falciferella is a welcome addition to our knowledge of an obscure group of ammonites, and its description affords an opportunity to review the Aconeceratidae and their distribution in Britain.

I am indebted to Mr. Milbourne for placing his specimens in my hands and for his company in the field, and to the Director of the Geological Survey and Museum for permission to publish information on the Gault of north Kent gained during the course of my official work. Professor H. H. Swinnerton and Mr. C. W. Wright have also facilitated this research by their generous loan of specimens of Aconeceratidae for study. Examination of comparative material in the British Museum (Natural History) was made possible through the courtesy of Dr. L. F. Spath, to whom I am further obliged for his vigorous criticism of my views on the Aconeceratidae.

2. STRATIGRAPHICAL AND FIELD OCCURRENCES OF *FALCIFERELLA*

In the scheme of zonal classification proposed by Spath (1941, p. 668) the Lower Gault of Kent comprises, in ascending order, the three Middle Albian zones of *Douvilleiceras mammillatum*, *Hoplites dentatus* and *Euhoplites lautus*. The *dentatus* Zone, which concerns us here, is divisible into the subzones of (1) *Hoplites benettianus*, (2) *Hoplites dentatus* and *Hoplites spathi*, (3) *Anahoplites intermedius*, and (4) *Dimorphoplites niobe*. Fig. 1 illustrates comparative sections in the *dentatus* Zone of Kent and the known occurrences of *Falciferella*. These, it will be noted, are confined to the *intermedius* Subzone. At Folkestone this subzone comprises the top part of Bed 1 and the whole of Bed 2 and is 6–7 ft. in thickness. It consists in the main of a dark grey clay, almost black when wet, with fossils in a pink, lustrous preservation, though mostly crushed. In a preliminary search of the section at Copt Point, Folkestone, the author failed to find *Falciferella* either in Bed I or in the line of nodules which marks the base of Bed II, but it occurred sporadically through the succeeding 4 ft. of Bed II and was found to be plentiful in a band of crushed fossils 7–8 in. below the base of Bed III (*niobe* Subzone).

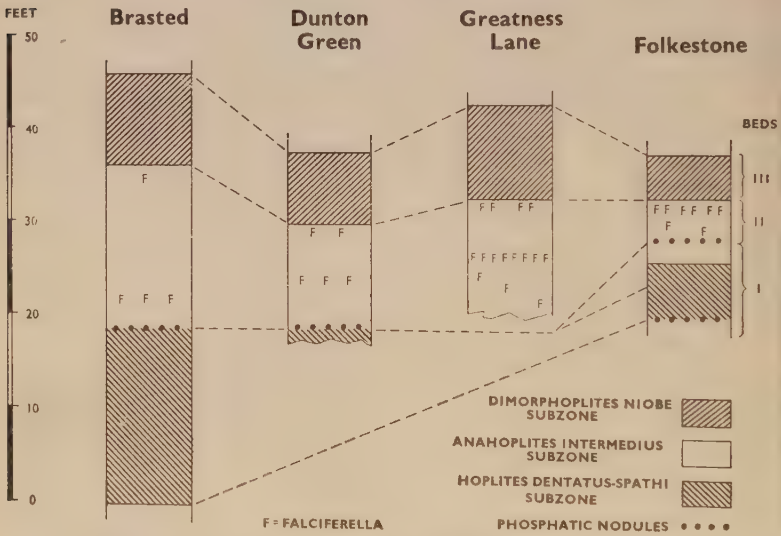

FEET
50
40
30
20
10
0
Brasted
Dunton Green
Greatness Lane
Folkestone
BEDS
III
II
I
F
DIMORPHOPLITES NIOBE SUBZONE
ANAHOPLITES INTERMEDIUS SUBZONE
HOPLITES DENTATUS-SPATHI SUBZONE
F = FALCIFERELLA
PHOSPHATIC NODULES • • • •

Fig. 1. Comparative vertical sections in the *Hoplites dentatus* zone of the Gault of Kent, showing occurrences of *Falciferella*

The principal collections of *Falciferella* have been made from the Gault of the Sevenoaks district. Our knowledge of the Gault in this area has been derived principally from the workings of the Dunton Green Brick, Tile and Pottery Works, near Dunton Green Railway Station, in which the succession has been described by C. W. Wright (*in* Wright & Thomas, 1946). This, combined with the sections exposed in the Sevenoaks Brick Company's pit at Greatness Lane, Sevenoaks, and in the sinking of a Metropolitan Water Board well at Brasted, has enabled a clear picture to be obtained of the Lower Gault sequence in this part of Kent. The chief features of the succession here as compared with that of the type section at Folkestone are the expansion of the *dentatus* Zone, which is here twice as thick as at Folkestone, and the attenuation of the overlying *lautus* Zone.

The Greatness pit lies three-quarters of a mile NE. of Sevenoaks (Bat and Ball) Railway Station and about one-third of a mile north of the Sevenoaks Brick Company's office buildings. An outline of the succession here has been given by M. H. Khan (1952), who has studied the foraminiferal content of the clays. It commences in the *intermedius* Subzone of the *dentatus* Zone, of which about 12 ft. are exposed. In lithology and in the mode of occurrence of the fossils the clay agrees closely with that observed at Folkestone, and the junction with the *niobe* Subzone above is similarly defined both palaeontologically and by the sudden change of the clay to a fawn-grey colour. This colour-change provides a conspicuous datum-line across the face of the pit.

After a systematic search of the Greatness section by Mr. Milbourne and the author, occurrences of *Falciferella* were found to be restricted to the *intermedius* Subzone. About a dozen specimens (including the holotype of the species) were found in the inch or two of clay immediately below the base of the *niobe* Subzone. The most productive horizon, however, was located 6–7 ft. lower, in a rich band of crushed fossils just below a line of phosphatic nodules with 'solid' *Anahoplites* body-chambers. Here, more than forty specimens of *Falciferella* were collected in about an hour, it being in fact the commonest ammonite at this horizon. Proceeding downwards, we obtained isolated specimens at intervals through the remaining five or six feet of clay to the floor of the pit. Associated with *Falciferella* was the normal fauna of the *intermedius* Subzone, including the ammonites *Anahoplites planus* (Mantell), *A. intermedius* Spath, *A. praecox* Spath, *A. mantelli* Spath, *Hoplites dentatiformis* Spath, *Hamites attenuatus* J. Sow. and *Protanisoceras nodosum* (J. de C. Sow.).

The section of the Gault at Dunton Green is broadly similar to that of the Greatness pit, about one-and-a-quarter miles to the east. The lowest horizon present at Dunton Green lies in the *dentatus–spathi* Subzone, of which only a foot or so is exposed in the floor of the pit. This is overlain by a nodule-bed containing ammonites characteristic of both the *dentatus–spathi* and the succeeding *intermedius* Subzones and which thus represents in condensed form the upper half of Bed I of Folkestone. About 12 ft. of clay above this nodule-bed are referable to the *intermedius* Subzone and are followed, as at Greatness, by the lighter-coloured clays of the *niobe* Subzone. Present conditions at the Dunton Green workings do not permit the sequence to be examined with the same facility as is afforded at Greatness. Nevertheless, independent visits to the pit by Mr. Milbourne and the author produced specimens of *Falciferella* from about 6 ft. and from 10 in. below the base of the *niobe* Subzone.

The Metropolitan Water Board well at Brasted penetrated the Lower Gault to a depth considerably exceeding that visible in the surface exposures at Greatness Lane and Dunton Green. The well is situated one-fifth of a mile SE. of the Railway Station and one-fifth of a mile NE. of St. Martin's Church, Brasted, and about three-and-a-half miles ESE. of Dunton Green. During sinking operations the site was visited at intervals in 1948 by the author in the course of his official duties and the following summarised account of the strata traversed in the sinking is given with official permission.

> The *dentatus* Zone was entered at about 12 ft. from the surface. The *niobe*, *intermedius* and *dentatus–spathi* Subzones, with characteristic fossils, were all present in descending order, and appeared to be of even greater vertical thickness than at the outcrop at Dunton Green and Greatness Lane. As would be expected, the same lithological characters of the clays were seen as at those localities, though the sharp colour-change at the junction of the *niobe* and *intermedius* Subzones was not apparent. A phosphatic nodule-bed at the base of the *intermedius* Subzone, like that at Dunton Green, was encountered at a depth of 38 ft. 6 in., and the underlying *dentatus–spathi* Subzone was proved to a thickness of nearly 20 ft. About 11 ft. of predominantly glauconitic sandy clay, representing the basal *dentatus* Zone (*benettianus* Subzone) and the *mammillatum* Zone, then intervened before the Lower Greensand was struck at a depth of 70 ft. from the surface.

Samples of fossiliferous clay from the Brasted well are stored in the Geological Survey and Museum, and these were critically examined for *Falciferella*. It was found at a depth of about 22 ft. (a small crushed example of 7 mm. diameter) and at 35 ft. (three additional specimens, 4, 5 and 12 mm. in diameter).

Specimens of *Falciferella* so far procured are mostly in a crushed condition. Commonly the septate nucleus is preserved as a pyrite-impregnated clay-mould, with the testiferous body-chamber crushed flat. A large proportion of the specimens are complete, though usually distorted, and judging by the range in size (from 4 to 30 mm. diameter), several generations may be present on one bedding-plane. The test is very thin and in the field it was noticed that specimens of *Falciferella* could often be picked out by the more metallic gleam of the nacre as compared with that of the other ammonites in the same bed.

It must be emphasised that the occurrences of *Falciferella* recorded above are based on limited collecting and should be regarded as a reconnaissance report. Sufficient evidence has been obtained to show that this little ammonite is a characteristic fossil of the *intermedius* Subzone of the Gault of Kent; but undoubtedly its geographical range will be extended by future collecting now that attention has been drawn to its presence. The possibility of its occurring also on other horizons in the Gault cannot be ruled out.

3. MORPHOLOGICAL FEATURES, SYSTEMATIC POSITION AND DISTRIBUTION OF THE ACONECERATIDAE

The Aconeceratidae comprise involute, strongly compressed ammonites, rarely exceeding 60 mm. in diameter. Ventral carination is typical and the keel may be high and continuous, minutely serrated, or, in the case of some Hauterivian forms described below, broken up into a cockscomb crest reminiscent of the Oxfordian *Creniceras*. In the new genus *Falciferella*, however, the venter is flattened and a keel appears only as a feeble and transient feature of early youth. The radial line is generally falciform or anguliradiate and the test may be almost smooth or provided with ribs which are confined to or emphasised on the upper half of the sides. Resemblance to Jurassic Oppeliidae is marked and it is a matter for speculation whether a form like *Sanmartinoceras groenlandicum* Rosenkrantz (1934, pl. 3, fig. 3; pl. 5, figs. 1–9), with long slender rostrum, apertural lappets, finely-toothed keel and *Ochetoceras*-like spiral groove, would have been recognised as Cretaceous if found isolated. The suture-line is also typically oppeliacean and is characterised by a deep, more or less symmetrically trifid, first lateral lobe and bifid, asymmetrical saddles, frequently with phylliform leaflets. The auxiliary saddles ascend obliquely forwards across the flank, a line joining their tops culminating at the prolonged dorsal portion of the first lateral saddle—a saddle which tends to dominate the whole suture-line. As pointed out by Sarasin (1893, p. 150), there is a coincidence in this family between the curvature of the septal edge and the falciform radial line.

Diverse opinions have been expressed concerning the origin and systematic position of the Aconeceratidae. Early authors generally referred the species now grouped in *Aconeceras* and its allies to *Oppelia*, but in keeping with modern evolutionary theory the resemblance to *Oppelia* has been regarded as due to convergence. The origin of the Aconeceratidae has thus been sought in the Desmoceratidae (Hyatt, 1903, p. 101 (footnote); Spath, 1923, p. 35; Wright, 1952, p. 219) and the Phylloceratidae, either directly (Whitehouse, 1926, p. 202), or via the Coilopoceratidae (Hyatt, 1903, p. 100). But these views rest on slender foundations. The capacity to produce oxycone extremes is admittedly inherent in all ammonite stocks, and if the Oppeliidae were indeed replenished by repeated offshoots from smooth, round-ventered haploceratid ancestors (Arkell, 1951, p. 356), it is not improbable that the Desmoceratidae, the successors of the Jurassic Haploceratidae, continued to generate *Oppelia*-like forms during the Lower Cretaceous. In support of the derivation of the Aconeceratidae from the Desmoceratidae, Spath (1923, p. 35) has pointed out the resemblance of the young *Pseudosaynella raresulcata* (Leymerie) to the desmoceratid *Callizoniceras*. Now, *Pseudosaynella*, by reason of its constrictions and suture line, stands apart from the other genera which have been assigned to the Aconeceratidae. It was dissociated from the Aptian '*Oppelia*' already by Sarasin (1893) (as *Sonneratia*) and by Kilian (1910) (as *Saynella*) and was transferred by Whitehouse (1926, p. 206) to the Cleoniceratidae as a supposed link between that family and the Aconeceratidae. Like *Neosaynella*, another Cretaceous homoeomorph of the Oppeliidae (Casey, 1954, p. 106), it has the sutural characters of a compressed desmoceratid,[1] with asymmetrical principal lobe and dominant external saddle. These genera probably descended, directly or indirectly, from the Desmoceratidae, but it is doubtful if they give any clue as to the origin of the Aconeceratidae. Hyatt himself appears to have abandoned the idea of a relationship between the Coilopoceratidae and the Aconeceratidae. Similarly, Whitehouse's view that the family is directly connected with the Phylloceratidae is not sustained at present by anything except involute coiling and the tendency for the saddles to become phylloid.

Against these theoretical speculations must be set the facts of morphology and stratigraphical continuity. Acknowledged survivors of the Oppeliacea have been described from the Valanginian and Hauterivian, as, for example, in Madagascar (Besairie, 1936, p. 143) and Southern France (Kilian & Reboul, 1915, p. 250): Aconeceratidae are now known to range from the Hauterivian to the Albian. Ultimately, it may be possible to show that the oppeliid pattern was merely an oft-repeated theme in the history of ammonite evolution, without genetic significance, and that stratigraphical continuity is an illusion. In the meantime, systematics must be based on present knowledge, and in default of evidence to the contrary, the author is strongly of the opinion that classification of the Aconeceratidae should be guided by their overwhelming morphological alliance with the Jurassic Oppeliacea. If the Oppeliacea are the polyphyletic assemblage envisaged by some authorities, the inclusion of the Aconeceratidae would scarcely disturb the systematic homogeneity of the superfamily.

With *Aconeceras* in North-west Europe, East Africa and Australia, and *Sanmartinoceras* in Patagonia, Australia, North-west Europe, Russia, and the Arctic, it is obvious that the Aconeceratidae had a world-wide distribution, yet recorded occurrences of the family are remarkably sporadic. It was not until the Aptian that the family assumed any importance, and even then its distribution appeared to have been very uneven. In Britain, for example, no *Aconeceras* is known from the Upper Aptian, yet the sudden influx of *Aconeceras nisum* (d'Orb.) in south-east France is used by Haug (1907, p. 1170) as an index of basal Upper Aptian times.

---

[1] The Speeton Clay forms recorded by Spath (1924, p. 78) as *Pseudosaynella plana* (Phillips *non* Mantell) are identified by the author as true desmoceratids, belonging to the Barremian group of *Barremites strettostoma* (Uhlig) (cf. Reg. No., G.S.M. 30973). The only British example of *Pseudosaynella* known to the author is from the Lower Greensand (Upper Lobster Bed) of Atherfield, Isle of Wight (G.S.M. Zm 1737).

Falciferella milbournei in the Gault of Kent indicates another such local oppeliid 'flood'. Whether by Lower Cretaceous times the Oppeliacea had taken to the open sea and entered neritic waters only during short periods when conditions were favourable to their growth is a matter of conjecture. In the present incomplete state of knowledge of the geographical occurrences of this family such conjecture, like Kilian's on a north–south migration of *Aconeceras nisum* (Kilian, 1913, p. 338), is premature.

Stratigraphical distribution of the various genera of the Aconeceratidae is as follows: *Protaconeceras* (Hauterivian), *Aconeceras* (Barremian–Lower Albian), *Sanmartinoceras* (*Theganeceras*) (Lower Aptian), *Sanmartinoceras s.s.* (Upper Aptian–Lower Albian), *Gyaloceras* (? Upper Aptian), *Falciferella* (Middle Albian).

The Australian genus *Gyaloceras* Whitehouse (1927, p. 114), said to be of Upper Aptian age, is the only member of the family not yet reported from Europe. It is here included in the Aconeceratidae only provisionally since it is unusually inflated and the suture-line has not been figured. A record of a doubtful *Aconeceras* from the Upper Albian of Angola (Haas, 1942, p. 165) suggests that the family may range upwards beyond the Middle Albian.

4. SYSTEMATIC ACCOUNT OF BRITISH ACONECERATIDAE

Genus: **PROTACONECERAS** nov.

Type species. *Oppelia patagoniensis* Favre (1908, p. 634–5, pl. xxxiv, fig. 7; pl. xxxvii, figs. 3–5; text-fig. 6), Lower Hauterivian, Patagonia.

Diagnosis. Micromorph oxycones having a strongly serrated keel in youth and a narrow umbilicus with very low, subvertical wall. Test finely ornamented by narrow, sinuous riblets, typically strap-like and continuous to the keel. Suture-line with more widely splayed lobes and shorter first lateral saddle than that of *Aconeceras*.

Remarks. Apart from the differences in the suture-line, this genus is readily distinguished from *Aconeceras* by its conspicuously toothed keel and the gentler curve of the radial line. The ornament of the type species is also distinctive, but a study of the Speeton material, discussed below, suggests that this feature is of subordinate taxonomic value. A tendency to flatten the ribs or costulae is manifest in a greater or less degree in all genera of the Aconeceratidae, just as the flat-topped ribs of the Upper Aptian *Colombiceras* appear sporadically in *Hypacanthoplites* and other genera of the Acanthohoplitinae. In any case, the ornament is but imperfectly reproduced on the internal mould, which may show only relatively widely-spaced rounded ridges (see Favre, 1908, pl. xxxiii, fig. 5). The type species is dated as Lower Hauterivian by its association with *Leopoldia*, *Argentiniceras* and *Lyticoceras*.

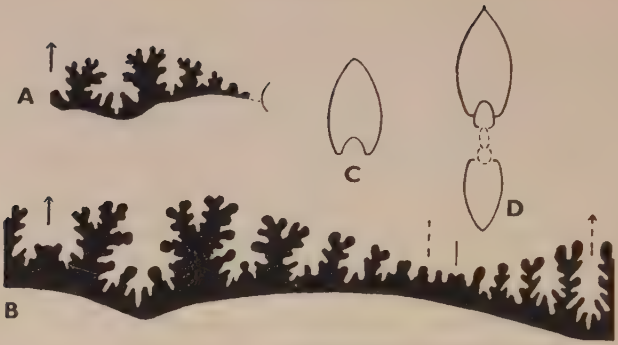


Fig. 2. Species of *Protaconeceras*. A, external suture line of *P. patagoniense* (Favre), Lower Hauterivian, Patagonia (after Favre) x 2; B, complete suture line of *P.* sp. nov., Upper Hauterivian (C 4 beds), Speeton Clay, Yorks. (C. W. & E. V. Wright Coll. 6261) x 9; C, whorl-section of same specimen, x 2; D, whorl-section of *P.* sp. nov., figured Pl. 7, fig. 7. Locality and horizon as for B and C. (C. W. & E. V. Wright Coll. 4445) x 2

Protaconeceras spp. nov.

Plate 7, Fig. 7; Text-fig. 2.

Remarks. The upper Hauterivian C 4 beds of Speeton have yielded to C. W. & E. V. Wright a suite of small aconeceratids of the *patagoniensis*-group, mostly in the form of pyritic internal moulds. One such mould, a septate half-whorl of 12 mm. diameter, shows already the degeneration of the peripheral crenulations as in the adult of *P. patagoniense* and the lateral riblets similarly maintain their strength right up to the keel. The suture line of this example is figured (Fig. 2, B) since both the external and internal portions are exposed, the latter showing slender-stemmed phylloid saddles. On the other hand, in the specimen illustrated as Plate 7, Fig. 7 the auxiliary saddles ascend with greater obliquity to a taller first lateral saddle, as in *Aconeceras*, and the sigmoidal riblets fade towards the periphery. This example is also an internal mould and is complete at 12 mm. diameter with half a whorl of body-chamber. Unfortunately the only specimens in the collection showing the test are very small nuclei or fragments; some show a subdued ornament of strap-like riblets; others are nearly smooth or with delicate, crowded ridges. Possibly transitions to *Aconeceras* are represented in this material. All, however, possess the saw-toothed keel and radial line of *Protaconeceras*. The material is inadequate for specific diagnosis and it must suffice here to record the presence of the genus in this country.

Genus: **ACONECERAS** Hyatt, 1903

Aconeceras nisoides (Sarasin)

Plate 7, Fig. 6

1893. *Oppelia nisoides* Sarasin, *Étude sur les Oppelia*, 155, pl. iv–vi, figs. 10a–c; text-figs. 3, 5.

1902. *Oppelia nisoides* Sarasin; v. Koenen (*pars*), *Amm. d. Nordd. Neocom.*, 51, pl. xvi, figs. 6a–c.
1906. *Oppelia nisoides* Sarasin; Danford, *Speeton Amm.*, pl. xiv, fig. 7.
1921. *Aconeceras nisoides* Sarasin; Spath, *Cret. Ceph. Zululand*, 311, pl. xxvi, figs. 4a–b; text-fig. B, 9.
1924. *Aconeceras nisoides* Sarasin; Spath, *Amm. Speeton Clay*, p. 78.
1935. *Aconeceras nisoides* Sarasin; Swinnerton, *Rocks below Red Chalk*, p. 24.

Remarks. A broad interpretation of Sarasin's species is made necessary by the fact that the type specimen, from the Aptian of the Haute Marne, is an internal mould and topotype specimens showing the test have not been figured. In view of the discrepancy which may appear between the ornament of the test and that of the mould in the aconeceratids, it is, therefore, impossible to be certain that the forms here discussed are all strictly conspecific with *A. nisoides*. The recorded range of the species, from Upper Barremian to Upper Aptian, is unusually long and suggests that more than one species may be involved.

A. nisoides has been recorded in the *Deshayesites bodei* Subzone of the Lower Aptian from the Speeton Clay of Yorkshire and the Sutterby Marl of Lincolnshire, though, curiously enough, it has never been found at Hunstanton, Norfolk, which is the principal source of the *bodei*-fauna in this country. There are about 20 pyritised specimens before me from Speeton (Top B beds), mainly from the Wrights' and the Danford Collections; most retain the test, which shows a good deal of variation in the strength and disposition of the riblets. Many of the internal moulds have good agreement with Sarasin's type; others are almost completely smooth, thus resembling the Timmern example of v. Koenen listed in the synonymy. The Sutterby specimens are mainly worn phosphatic moulds, but show no variation from comparable Speeton material.

Whitehouse (1926, p. 203) has suggested that the Speeton form, figured by Danford as *O. nisoides*, requires separation under a new name on account of its greater inflation. This suggestion is based on incorrect measurement of Danford's original, which is preserved in the Geological Survey Museum (G.S.M. 17916). It has dimensions as follows:

Diameter	23 mm.
Height of last whorl (as % of diam.)	51
Thickness of last whorl (,, ,,)	22
Umbilicus (,, ,,)	*c.*10

and this compares closely with the typical *nisoides*.

To this comprehensive *A. nisoides* is also referred the Atherfield example illustrated in Plate 7, Fig. 6. Like the Speeton forms, it has the dimensional proportions and the relatively simple suture-line of *A. nisoides*, but the riblets (on the test) are flattened and more irregular than those of the type. The keel is hollow and minutely serrated where covered by the test.

Aconeceras sp. nov.

1923. *Aconeceras*, Spath, *Monogr. Gault Amm.*, p. 38.
1947. *Aconeceras* sp., Wright & Wright (*pars*), *Albian Leighton Buzzard*, p. 166.

Remarks. Spath (1923, p. 38) recorded an example of *Aconeceras* from the Lower Albian (*Leymeriella tardefurcata* Zone) of Leighton Buzzard, Bedfordshire. This was not described in the Gault monograph because it was then believed to be possibly derived or merely a homoeomorphous or accidentally keeled development of the contemporary *Beudanticeras*. Subsequently, an additional specimen was collected from the same horizon and locality (Wright & Wright, 1947, p. 166) and it is now clear, from the preservation and mode of occurrence of these fossils, that they are indigenous to the *tardefurcata* Zone (*L. regularis* Subzone). The specimen mentioned by Spath is in the Geological Survey Museum (G.S.M. Z2657); it is 18 mm. in diameter, with the hollow inner whorls broken open to expose the septa and with the body-chamber preserved mainly as an internal mould in phosphorite. The test appears almost perfectly smooth, as in *A. nisum* (d'Orb.), but it is a more evolute form with a wider, less convergent whorl-section than d'Orbigny's species. The Wrights' specimen (16543), a nucleus of some 9 mm. diameter, is apparently conspecific. The species is new and will be figured on a later occasion when more material may be available.

The occurrence of *Aconeceras* in the *tardefurcata* Zone, albeit rare, emphasises the gaps in our knowledge of the distribution of this genus, which is otherwise unknown for certain above the Aptian.

Genus: **SANMARTINOCERAS** Bonarelli, *in* Bonarelli & Nagara, 1921

Subgenus: THEGANECERAS Whitehouse, 1926

Sanmartinoceras (Theganeceras) cf. **falcatum** (v. Koenen)

cf. 1902. *Oxynoticeras falcatum* v. Koenen, *Amm. d. Nordd. Neocom.*, 48, pl. xlv, figs. 7–8.
cf. 1926. *Theganeceras falcatum* (v. Koenen), Whitehouse, *Cret. Amm. E. Australia*, p. 202, footnote.
1935. *Aconeceras* sp., Swinnerton, *Rocks below Red Chalk*, p. 24.

Remarks. Among the collection of Cephalopoda made by Professor H. H. Swinnerton from the phosphate band in the Sutterby Marl of Sutterby, Lincs. (Swinnerton, 1935, pp. 24–6) is a small abraded fragment of a *Theganeceras*. In a length of 15 mm. it shows seven or eight flattened ribs whose strong forward projection at the middle of the sides suggests comparison with *S.* (*T.*) *falcatum* (v. Koenen) rather than v. Koenen's '*Oppelia*' *scalata*, the type species of *Theganeceras*. There is no previous record of *Sanmartinoceras* or *Theganeceras* in this country, and its occurrence in Lincolnshire provides another link between the Aptian deposits of our Northern basin and the North German succession. The Sutterby specimen is not necessarily contemporaneous with the *bodei* assemblage found in the same bed, since, as will be shown elsewhere, the Sutterby Marl phosphate band contains ammonites derived from more than one Aptian horizon.

Subgenus: SANMARTINOCERAS *s.s.*

? Sanmartinoceras (Sanmartinoceras) sp.

1947. *Aconeceras* sp., Wright & Wright (*pars*), *Albian Leighton Buzzard*, p. 166.

Remarks. Associated at Leighton Buzzard, with the *tardefurcata* Zone, *Aconeceras* discussed above is another small fragment of an aconeceratid in the C. W. & E. V. Wright Collection (19271), which, at 11 mm. diameter, has distinct falcate ribbing, rather too strong to permit reference to *Aconeceras*. It has the aspect of a juvenile *Sanmartinoceras*, but is too small for positive determination. The occurrence of this typically Upper Aptian genus in the *tardefurcata* Zone should occasion no surprise, since it has been recorded by Breistroffer (1947, p. 10) from south-east France in the intervening zone of *Diadochoceras nodosocostatum*, usually regarded in this country as basal Albian.

Genus: FALCIFERELLA nov.

Type species. *Falciferella milbournei* sp. nov.

Diagnosis. Micromorph platycones with narrow, sharp-rimmed umbilicus and tabulate venter, feebly carinate in early youth. Test with strongly falcoid lineation or subcostation, and a faint spiral groove at the middle of the sides. Mouth-border plain. Suture-line of simplified *Aconeceras* pattern, with reduced auxiliary elements.

Remarks. The attribution of *Falciferella* to the Aconeceratidae is made with reservation, since the tabulate venter is an abnormal feature in this family. Future discoveries may show the necessity of erecting a new family for its reception, but in view of the wide variety of ventral shapes assumed, for instance, in the Streblitinae, it seems advisable at present to regard this divergence from the normal aconeceratid venter as of no great taxonomic significance. Before the suture-line was prepared, it was considered possible that *Falciferella* was a development from certain oppeliid homoeomorphs of the *mammillatum* Zone, namely the group of *Cleoniceras* (*Neosaynella*) *inornatum* Casey. These have narrow tabulate venters in the adolescent and a strongly falcoid radial line, but the sutural characters are those of normal *Cleoniceras* and are against association with *Falciferella*. *Neosaynella* is of interest, however, as showing, like *Falciferella*, the tendency in a normally oxycone stock to flatten the venter and thus simulate certain contemporary Hoplitinae. It is probably because of its superficial similarity to the common *Anahoplites planus* (Mantell) that *Falciferella* has been hitherto overlooked.

Falciferella milbournei sp. nov.

Plate 7, Figs. 1–5; Text-fig. 3

Material. The holotype (G.S.M. 86000; R. A. Milbourne Colln.), and paratypes (G.S.M. 85997–85999, 86011, 86012; R. A. Milbourne Colln., and Zm 1772–1774, 1777, 1780, 1781, 1785, 1787, 1790, 1791, 1793, 1796–1798; R. Casey Colln.) from the Greatness Lane pit, Sevenoaks, Kent; paratypes (Zm 1801–1803; R. Casey Colln.) from Copt Point, Folkestone, Kent; and about 40 other specimens from Sevenoaks, Dunton Green, Brasted and Folkestone.

Horizon. Lower Gault (Middle Albian), *Hoplites dentatus* Zone, *Anahoplites intermedius* Subzone.

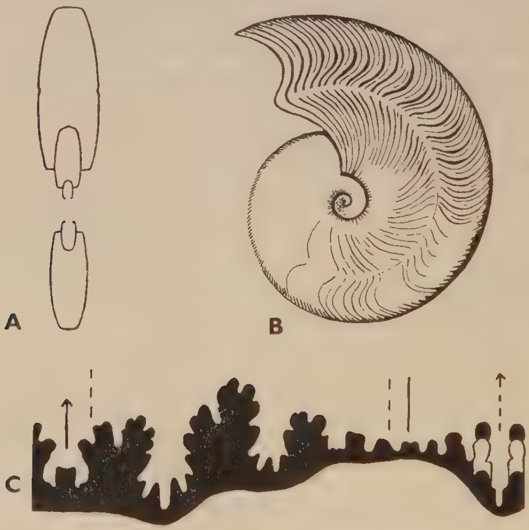


Fig. 3. *Falciferella milbournei*, gen. et sp. nov. Diagrammatic whorl-section, (A) and lateral view (B), both x 2, with complete suture line of paratype G.S.M. 86012 (h.c.), enlarged x 7

Description. Whorls strongly compressed, progressively involute, subrectangular in section with greatest thickness about mid-flank; venter at first gently convex, later (between 5 and 10 mm. diameter) the median line is raised into a feeble carina which fades away until the venter is quite flat; ventro-lateral edges blunt; umbilical wall very low, perpendicular and smooth. Fine ridges on test are directed radially from the sharp umbilical rim and then sweep forwards across the flanks in a wide arc concave towards the aperture. At mid-flank they are produced into a broad, blunt lingua, ventral of which they form an asymmetric crescent with a strong forward projection towards the venter. They are bent forwards into a lappet on the venter. Both individually, and in different growth-stages of the same specimen, there is great irregularity in the spacing and prominence of the ridges, not entirely due to vagaries of preservation. They are strongest on the upper lateral area and frequently obsolete at the rim of the umbilicus. In general they are accentuated and relatively more widely spaced in the young, ranking as subcostae, but occasionally, as in the holotype, the ridges rejuvenate and coarsen towards the end of the body-chamber of the adult. With increase in diameter there is a tendency for the ornament to differentiate into flattened primary ridges and subsidiary hair-like striae, the latter intervening between and superimposed on the ridges. The body-chamber is rather more than half a whorl in length, and the faint spiral groove, coinciding with the tip of the lingua, is rarely discernible below 15 mm. diameter. Suture-line interlocking, rather simple, especially as regards the internal portion; external lobe narrow, with subquadrate median saddlet straddled by two simple lobules; first lateral lobe narrow, trifid, subsymmetrical; second lateral lobe symmetrically bifid; first lateral saddle strongly asymmetric, oblique on the top ventral side, dwarfing the external saddle, as usual in the Aconeceratidae.

Measurements.	86000[1]	86012[2]	86011[3]	Zm 1798[4]
Diameter	25 mm.	14 mm.	11 mm.	8 mm.
Height of last whorl (as % of diameter)	52	50	52	45
Thickness of last whorl (as % of diameter) ...	?	20	21	?
Umbilicus (as % of diameter)	12	16	18	23

[1] Crushed ; complete to mouth-border; septate to 14 mm.
[2] Maximum diameter, with crushed body-chamber, *ca*. 25 mm.; septate to 14 mm.
[3] Septate nucleus.
[4] Juvenile; crushed.

	86000	Zm 1777	Zm 1781	Zm 1798	Zm 1798
Diameter ...	25 mm.	*ca*. 20 mm.	at 15 mm.	8 mm.	at 7 mm.
Segment of test (measured at lingua apicad from last radial line)	10 mm.	5 mm.	5 mm.	2 mm.	2 mm.
Number of ridges	12	12	10	16	12

Remarks. Reference has already been made to the superficial resemblance of this species to the young of *Anahoplites planus* (Mantell). Under the lens the adult *Falciferella* is readily identified by its strongly bent growth-lines, faint spiral groove, narrow, sharp-rimmed umbilicus, and the absence of the delicate umbilical and ventro-lateral tubercles of *A. planus*. The relatively open umbilicus of the young (a feature common to all aconeceratids) may make discrimination of small specimens difficult, but a Folkestone example of *F. milbournei* (G.S.M. Zm 1801), with nucleus scarcely crushed, shows already at 3 mm. diameter compressed whorls, steep umbilical wall and neatly truncated venter, at which stage *Anahoplites* has the inflated, rounded whorls of a *Desmoceras*. The suture lines of the two genera are quite different.

EXPLANATION OF PLATE

Fig. 1. *Falciferella milbournei* gen. et sp. nov. Lower Gault (Middle Albian), *H. dentatus* Zone, *A. intermedius* Subzone, 2 in. below *D. niobe* Subzone. Greatness Lane pit, Sevenoaks, Kent. Holotype (R.A. Milbourne Colln., G.S.M. 86000) x 2.

Fig. 2. *Ibid.* Juvenile specimen showing open umbilicus. Locality as for Fig. 1; 6 ft. below *D. niobe* Subzone. Paratype (R. Casey Colln., G.S.M. Zm 1798) x 4.

Fig. 3. *Ibid.* Body-chamber fragment crushed obliquely and showing venter. Locality and horizon as for Fig. 2. Paratype (R. Casey Colln., G.S.M. Zm 1777) x 2.

Fig. 4. *Ibid.* Uncrushed septate nucleus; (a) lateral view, (b) ventral view showing feeble carina. Locality and horizon as for Fig. 2. Paratype (R. A. Milbourne Colln., G.S.M. 86011) x 2.

Fig. 5. *Ibid.* External suture-line at 3 mm. diameter. 7–8 in. below *D. niobe* Subzone, Copt Point, Folkestone, Kent. Paratype (R. Casey Colln., G.S.M. Zm 1801) x 20.

Fig. 6. *Aconeceras nisoides* (Sarasin) *s.l.* Lower Greensand (Lower Aptian), *Deshayesites deshayesi* Zone, Atherfield, Isle of Wight (L. F. Spath Colln., G.S.M. 57704) x 2.

Fig. 7. *Protaconeceras* sp. nov. Speeton Clay (Upper Hauterivian, C 4 beds), Speeton, Yorkshire. (C. W. & E. V. Wright Colln., 4445) x 2.

LIST OF REFERENCES

Arkell, W. J. 1950. A classification of the Jurassic ammonites. *Journ. Paleont.*, **24**, 354–64.

Besairie, H. 1936. Recherches géologiques à Madagascar, I. La géologie du Nord-Ouest. *Mém. Acad. Malgache*, fasc. 21, 1–259.

Breistroffer, M. 1947. Sur les zones d'ammonites dans l'Albien de France et d'Angleterre. *Trav. Lab. géol. Grenoble*, **26**, 1–88.

Casey, R. 1954. New genera and subgenera of Lower Cretaceous ammonites. *Journ. Washington Acad. Sci.*, **44** (4), 106–15.

Danford, C. G. 1906. Notes on the Speeton ammonites. *Proc. Yorks. Geol. Soc.*, (N.S.) **16** (1), 101–14.

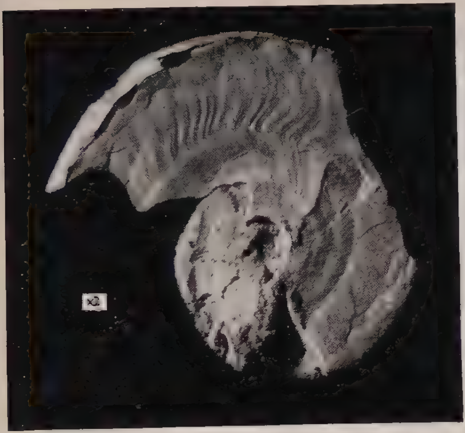
Favre, F. 1908. Die Ammonitiden der unteren Kreide Patagoniens. *Neues Jahrb. f. Min. Geol.*, **25**, 601–47.

Haas, O. 1942. The Vernay collection of Cretaceous (Albian) ammonites from Angola. *Bull. Amer. Mus. Nat. Hist.*, **81** (1), 1–224.

Haug, E. 1907. Traité de géologie, II. Les Périodes Géologiques, fasc. 2, Période Crétacée, 1153–396.

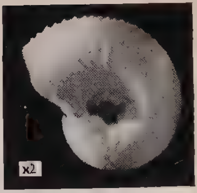
Hyatt, A. 1903. Pseudoceratites of the Cretaceous. *Mon. U.S. Geol. Surv.*

Khan, M. H. 1952. Zonal analysis of the Lower Gault of Kent based on Foraminifera. *Contr. Cushman Found. Foram. Res.*, **3** (2), 71–80.

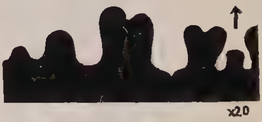


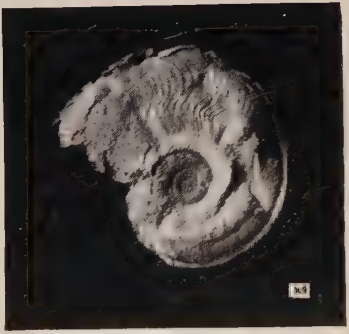
1

7

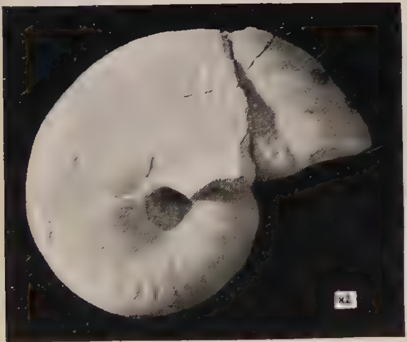


5

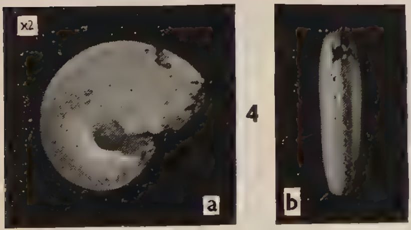




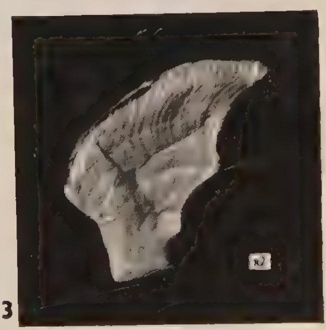
2



6



4



3

BRITISH ACONECERATIDAE

[*To face p.* 276

KILIAN, W. 1910. Un nouvel exemple de phénomène de convergence chez les ammonitidés; sur les origines du groupe de l'*Ammonites bicurvatus*, Mich. (sous-genre *Saynella* Kilian). *C.R. Acad. Sci. France*, **150**, 149–52.

———. 1913. Unterkreide (Palaeocretacicum). *In* Frech: Lethaea Geognostica, ii, Mesozoic, Lief 3, 289–398.

——— & P. REBOUL. 1915. Contribution à l'étude des faunes paléocrétacées du Sud-est de la France, II. Sur quelques ammonites de l'Hauterivien de la Begude (Basses-Alpes). *Mém. Carte géol. France*, 223–88.

KOENEN, A. v. 1902. Die Ammonitiden des Norddeutschen Neocom., *Abh. d. k. Preuss. Geol. Land.* (N.F.), No. 24, 1–451.

ROSENKRANTZ, A. 1934. *In* Bøgvad and Rosenkrantz: Beiträge zur Kenntnis der Unteren Kreide Ostgrönlands. *Medd. om Grønland*, **93** (1), 17–28.

SARASIN, CH. 1893. Étude sur les *Oppelia* du groupe du *nisus* et les *Sonneratia* du groupe du *bicurvatus* et du *raresulcatus*. *Bull. Soc. géol. France*, (3), **21**, 149–64.

SPATH, L. F. 1921. On Cretaceous Cephalopoda from Zululand. *Ann. S. African Mus.*, **12** (7), 217–321.

———. 1923–43. A monograph of the Ammonoidea of the Gault. *Monogr. Palaeontogr. Soc.*, London.

———. 1924. On the ammonites of the Speeton Clay and the subdivisions of the Neocomian. *Geol. Mag.*, London, **61**, 73–89.

SWINNERTON, H. H. 1935. The rocks below the Red Chalk of Lincolnshire and their cephalopod faunas. *Quart. Journ. Geol. Soc. Lond.*, **91**, 1–46.

WHITEHOUSE, F. W. 1926. The Cretaceous ammonoidea of Eastern Australia. *Mem. Queensland Mus.*, **8** (3), 195–242.

———. 1927. Additions to the Cretaceous ammonite fauna of Eastern Australia. *Mem. Queensland Mus.*, **9** (1), 109–20.

WRIGHT, C. W. 1952. A classification of the Cretaceous ammonites. *Journ. Paleont.*, **26**, 213–22.

——— & H. D. THOMAS. 1946. Notes on the geology of the country round Sevenoaks. *Proc. Geol. Assoc.*, **57**, 315–21.

——— & E. V. WRIGHT. 1947. The stratigraphy of the Albian Beds at Leighton Buzzard. *Geol. Mag.*, London, **84**, 161–8.

Summer Field Meeting in the Massif Central

10—23 September 1951

Report by M. ROQUES, P. LAPADU-HARGUES and R. BRADSHAW

Directors: M. Roques, P. Lapadu-Hargues; assisted by R. Michel and M. Peterlongo

Received 3 February 1954

CONTENTS

1. INTRODUCTION TO THE GEOLOGY OF THE MASSIF CENTRAL ... ... *page* 278
2. DAILY ITINERARY 289
BIBLIOGRAPHY 311

---

1. INTRODUCTION

THE FOLLOWING ACCOUNT is in the main a translation of the Livret Guide prepared by Professor Roques and Dr. Lapadu-Hargues for the visit of the Association in the summer of 1951. There have been one or two minor additions based on previous guides listed in the bibliography.

The Massif Central is built up of a series of geological units as follows:

(e) Quaternary volcanics.
(d) Miocene and Pliocene volcanic massifs.
(c) Eocene and Oligocene deposits.
(b) The Mesozoics of the Causses.
(a) The Basement.

(a) **The Basement.** This is a complex of crystalline schists, granites and folded Devonian and Carboniferous strata. The basement rocks are found in regions which suffered peneplanation during the Mesozoic, and subsequent fracturing and uplift in the Tertiary. Erosion following these latter movements has given rise to narrow, deep valleys often with incised meanders.

It is not possible to put a precise age to the crystalline series. In the south of the Massif Central—in the Montagne Noire—Pre-Cambrian rocks can be shown to underlie metamorphosed Cambrian and Silurian strata while the transgressive Devonian rocks are only slightly metamorphosed and the Viséan sediments are unaltered. In the north no member of the series can be dated but, at Châteauneuf, unaltered Viséan rocks rest on the crystalline

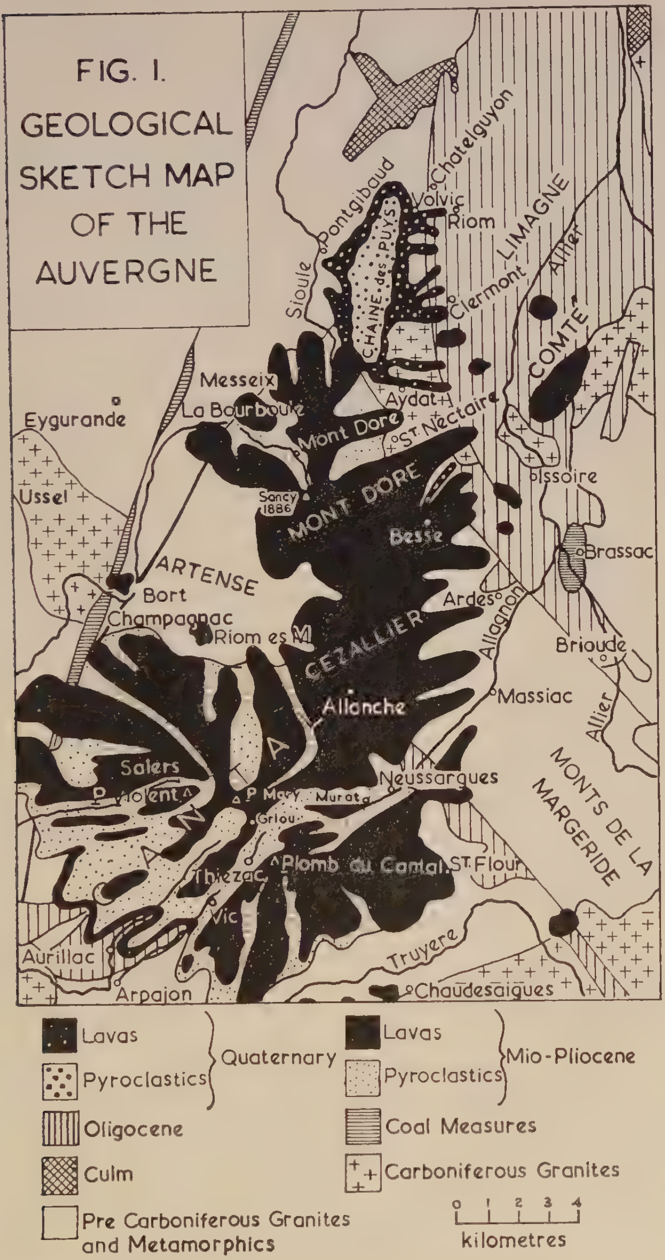


FIG. I. GEOLOGICAL SKETCH MAP OF THE AUVERGNE

basement and, in the Morvan, fossiliferous Devonian sediments rest discordantly on highly metamorphosed rocks. The metamorphism is thus pre-Devonian in the north but affects both the Devonian and Lower Carboniferous in the south of the Massif.

It is in this region that Jung and Roques have distinguished between *ectinites*, in which metamorphism has been achieved without appreciable addition of granitic material, and *migmatites*, where this granitic addition has been considerable. The subdivisions of these two main groups are found to possess a certain stratigraphic significance.

The following zones, based on changes in the pelitic rocks, can be recognised in the ectinites as they are traced towards the cores of the anticlines.

Zone	*Characteristic Rock Type*
Schistes	Shales
Micaschistes supérieurs	Sericite chlorite schists
Micaschistes inférieurs	Biotite schist
Gneiss supérieurs	Muscovite biotite gneiss
Gneiss inférieurs	Biotite gneiss

In the migmatites it is possible to recognise two main groups on textural grounds. These are the *Embrechites* in which, in spite of addition of granitic material, the foliation is well preserved, and the *Anatexites*, in which the foliation becomes discontinuous, much contorted or even nebulous. The migmatites are below the ectinites but the height of the migmatite 'front' is not constant, being in the zone of the *gneiss supérieurs* in the Bas Limousin but in the *gneiss inférieurs* in the Moyenne Dordogne and in the Auvergne. There are, however, isolated lenticles of migmatites within the main ectinite series and above the main migmatite front.

In some regions, e.g. the Bas Limousin, there is a normal sequence of the above metamorphic zones and thus there is a passage from ectinites to migmatites towards the core of the anticlines, but in the Moyenne Dordogne and in La Sioule, as a result of later tectonic inversion, this sequence is reversed and the schists dip beneath the gneisses and migmatites.

The granites of the basement fall into three main groups:

(a) *Anatectic granites*, as in the Cevennes, where the migmatites merge into granites which form the lowest member of the crystalline series. The migmatites are often cut by later granites, e.g. Cornil, which are, however, related to them.

(b) *Syntectonic granites*, such as that of Millevaches, which generally have oriented textures, irregular migmatitic patches in the interior of the massif, and sharp contacts with the country rock. They are parallel to the fold axes.

(c) *Post-tectonic granites* with sharp contacts cutting across fold directions and metamorphic zones. They are unorientated, homogeneous and produce contact metamorphic effects without felspathisation. In the north some of these intrusions, e.g. Châteauneuf, are pre-Viséan, and some, e.g. Mayet-de-Montagne, are post-Viséan.

The major folding in the north was pre-Devonian, followed by three phases of Hercynian movement: Tournaisian–Viséan, Viséan–Stephanian and Stephanian–Permian. In the south, and probably in the west also, the pre-Devonian movements were less intense and the major period of folding was between the Viséan and the Stephanian, with another phase post-Stephanian. The pre-Stephanian movements were followed by fracturing of the basement, giving rise to long faults such as the *dislocation d'Argentat* and the *sillon houiller* and, along these, mylonites are developed. There has been renewed movement along the latter fault in post-Stephanian times.

The basement can be regarded as being formed of several regional units. The general characters and limits of these will be given here but the details will be found in the day-to-day itinerary.

1. *La Sioule* is bounded in the west by the *sillon houiller*, in the east by the Limagne and in the south by the Chaîne des Puys. The granite of Châteauneuf is associated with this series of metamorphic rocks, which have suffered later tectonic inversion.

2. *La Moyenne Dordogne* is situated between the *sillon houiller* to the east, the massif of Millevaches to the west, and the Cantal to the south. Metamorphic zones from *micaschistes inférieurs* to *anatexites* are developed and the associated granites are those of Ussel and Meymac.

3. *Le Bas Limousin* has the Argentat fault to the east and younger sediments to the west. The granites of Saut de Saumon and Comborn are found within this series, which comprises a slate to migmatite sequence.

4. *The Millevaches* massif consists essentially of *micaschistes* into which is intruded the Millevaches *granulite* (two mica granite). It is bounded in the west by the Argentat fault, in the south by the Cantal and in the east by the Moyenne Dordogne massif.

5. *The Margeride and Lot* massifs are the dominant structural element in the southern part of the Massif Central and are bounded by the Rivers Lot, Middle Truyere and Upper Allier. A 'porphyroide' granite and granulites cut a micaschist-sillimanite gneiss series.

Devonian and Dinantian rocks are found mainly in the Ardoisière and Ferrières basins to the east of the Limagne, and, to a lesser extent, at Châteauneuf-les-Bains and Château-sur-Cher to the west of the Limagne.

The succession, established in the Ardoisière basin is as follows:

	Stratigraphic Division	Rock Types
Upper Viséan	Anthracitic tuffs	Tuffs with flows of rhyolite, trachyte and dacite. Conglomerates, thin beds of anthracite and fossiliferous shales. *Productus latissimus* *P. giganteus.*

	Stratigraphic Division	Rock Types
Lower Viséan	Greywacke-conglomerate	Conglomerates with crinoidal limestone bands. Greywackes with *P. cora* *P. hemisphaericus*
Tournaisian	Ardoisière shales	Black shales with sandstones and conglomerates at the base. Plant débris (compares with Morvan)
Upper Devonian	Andesite complex	Andesite flows and tuffs with unfossiliferous sandstones and shales. (Compares with a similar fossiliferous sequence in Morvan).

The same succession is present in the Ferrières basin, but there all beds have been contact-metamorphosed by the granite of Mayet-de-Montagne, whereas only the margins of the Ardoisière basin have been so affected.

The greater part of the succession is missing at Châteauneuf and Château-sur-Cher, and only the uppermost division, the anthracitic tuffs, is present.

The Stephanian rests on a basement which had been strongly folded and deeply eroded during the Westphalian. The deposits, entirely lacustrine and deposited in intermontane basins, are conglomerates, sandstones, arkoses, shales with plants and fresh-water molluscs, coals and beds of white clay. The type succession is that of the St. Etienne basin:

	Series	Characteristic fossil
Upper Stephanian	Avaize series	*Odontopteris minor*
Middle Stephanian	St. Etienne series	*Odontopteris reichiana* *Cordaites lingulatus*
Lower Stephanian	Rive de Gier series	*Pecopteris lamurensis* *Pecopteris arborescens*

Other basins include a series along the *sillon houiller*, in which the deposits have been strongly folded, and those of Brassac and Langeac in the south of the Limagne, where there has been only gentle folding.

(b) **The Causses.** This large area in the south of the Massif Central is made up of mainly Mesozoic sediments, predominantly limestones, which attain a thickness of 5000 ft. These give rise to a characteristic morphology which contrasts strongly with the neighbouring crystalline regions. The area is crossed by the Tarn and its two main tributaries, the Jonte and the Dourbie, which all flow through very deep gorges and are in fact the only surface waters. The deep valleys of these rivers divide the Causses into a number of minor units each with a special name.

Causse	*Area*
Sauveterre	N. of the Tarn.
Méjan	Tarn–Jonte
Noir	Jonte–Dourbie
Larzac	S. of the Dourbie
Sévérac Comtal	In the Détroit de Rodez, NW. of the main Causses region.

The sediments are mainly Jurassic and rest either on the crystalline basement on Stephanian or on Permian rocks.

Succession:

Portlandian	Oolitic limestone.
Kimmeridgian	Grey unbedded dolomite (Upper Dolomite). This forms the upper ledge of the Tarn gorges.
Lusitanian	Lithographic and thinly bedded limestones.
Callovian–Oxfordian	Thin marls. Crystalline limestone.
Bathonian	Grey unbedded dolomite (Lower Dolomite). This forms the floor of the gorges of the Jonte and of the Tarn (except between Sainte Enimie and Les Bannes).
Bajocian	Cavernous dolomite. Entroques limestone. *Cancellophycus* limestone. This forms the second ledge on the northern margins of the Causse.
Toarcian and Aalenian	Blue-black marls.
Charmouthian	White, slightly marly, limestones, rich in sponge spicules.
Sinemurian	Hard crystalline oolitic limestone. Forms first ledge on the N. borders of the Causse.
Hettangian	Alternations of dolomitic limestones and green and yellow marls. Dolomite (present only in the east).
Infra-Lias	Sandstones of variable thickness.

The underlying Permian consists of sandstones, conglomerates and red, sandy clays of a continental series found only in the Détroit de Rodez.

Dolomitisation is widespread throughout the whole region. At any one locality it may affect great vertical thicknesses of limestone and yet be quite restricted laterally.

The Plateau of the Causses has not been folded but it has suffered extensive fracturing mainly during the Pyreneean and Alpine orogenic episodes but with activity continuing into the Aquitanian. The faults are either N.–S., e.g. the Marvejols–Aumont–Aubrac line or WNW.–ESE., e.g. the faults bounding the Détroit de Rodez and the Chanac–Aubrac line. Igneous activity accompanying this fracturing was initiated at an uncertain date but persisted into the Quaternary. The rocks are mainly basaltic, with some few limburgitic in character, and they occur as volcanic cones and as small laccoliths within the Jurassic sediments.

(c) **Eocene and Oligocene Deposits.** The effect of the early Tertiary (Pyreneean) earth movements in the Massif Central was to produce a series of depressions in which were deposited lacustrine and occasionally brackish water sediments of Eocene and Oligocene age. Sedimentation began in the Eocene in the small isolated basin of Menat, where bituminous paper shales yield algae, diatoms, sponge spicules and a rich insect and fish fauna and an equally rich flora.

The main basins, however, are those of the Limagne and of Aurillac. The succession in the Limagne is:

	Fossils	N. Limagne	Clermont
Aquitanian	*Helix arvenensis* *Melania aquitanica*	Upper concretionary limestones (Phyrganes) Rich vertebrate fauna	Sands and clays.
Chattian	*Helix ramondi*	Lower concretionary limestones	Limestones and marly limestones
U. Stampian	*Potamides lamarcki*	*Cypris*-bearing marls	Marls with *Cypris*. Gypsiferous marls Concretionary limestones. Sandy towards the margins of the basin.
M. Stampian	*P. lamarcki*	Marls	Marls and limestones.
L. Stampian		Arkoses	Gypsiferous marls and limestones. Sands and Arkoses.
Sannoisian	*Striatella barjacensis* *Nystia* *Potamides*	(Absent)	Sands, arkoses and variegated clays, found only in the S. near Issoire.

The Stampian varies in thickness in the Limagne basin ranging from 1000 ft. in the east, near Puy Saint Romain, to 5400 ft. in the centre, near Riom. In the Aurillac basin, however, the Stampian is represented by only 450 ft. of sediments.

In addition to these sediments in the Limagne there are beds of *pépérites*—rocks consisting of small fragments of glassy lava in a matrix of marl, limestone or silica. They were formed by sub-lacustrine explosions when lava came into contact with the water. In some cases they are well bedded, while in others, nearer to the eruptive centres, the stratification disappears and they take on the form of mud-flows and occasionally appear to fill an actual neck as at the Puy de Crouël.

The Aurillac basin succession is:

	Fossils	Rocks
Aquitanian	*Planorbis hautelli*, *Limnea dilatata*	Grey limestones.
U. Stampian	*Planorbis cornu*, *Helix corduensis*	Massively bedded limestones.
M. Stampian	*Potamides lamarcki*, *Nystia duchastelli*	Alternations of clays and cherty limestones. White marls with *Cypris*.
L. Stampian	—	Sands and red clays.

(d) **Tertiary Volcanic Massifs.** During the Miocene and Pliocene were formed the large volcanic massifs of the Mont Dore, Cantal and Aubrac, while in the same period there was activity on a more restricted scale in the Limagne.

(i) *Limagne*. The succession in the Plateau de Gergovie, near Clermont Ferrand, illustrates the relations of the volcanic rocks to the associated sediments.

Upper Burdigalian	Upper analcite basanite.
	Felspathic sands as infilling of channels in the flow below.
	Lower analcite basanite.
Middle Burdigalian	Green marls with *Melania* (an old valley infilling).
Aquitanian	Limestones with *pépérites* and a basalt sill.

Similar rocks are found in the Côtes de Clermont, Puy de Mur and at Puy St. Romain.

(ii) *The Mont Dore*. This is a strato-volcano formed by such a great and widespread accumulation of ejected material that the associated lavas rarely flowed beyond the limits of the débris to rest directly on the basement. In this respect the Mont Dore and the Cantal differ from the other Auvergne volcanoes. The Pic du Sancy (5820 ft. approx.) is the highest part of this fairly regular cone whose diameter is about thirty kilometres. There is a gentle slope towards the margins but water- and ice-erosion have cut deeply into the once even surface.

The main succession is:

3. *Coulées des plateaux*—Pliocene.
2. *Cinérite supérieure*—Pliocene.
1. *Cinérite inférieure*—Miocene.

and rests on a faulted granitic basement.

1. CINÉRITE INFÉRIEURE. In the small restricted basin of La Bourboule are found the basal members of the Mont Dore massif. There are about 500 ft. of fine *cinérites* with sands, gravels and diatomaceous clays yielding a rich Pontian flora. Acid intrusions, such as the phonolitic trachyte of Pessy and the rhyolites of Lusclade, cut the *cinérites inférieures*.

2. CINÉRITE SUPÉRIEURE. This forms the main mass of the Mont Dore and consists of explosion breccias with huge blocks, agglomerates and ashes called *cinérites à blocs*. It is very thick in the centre of the cone, thins out gradually to the periphery and is interbedded with many flows and cut by many dykes with a range of composition from basaltic to trachytic. At La Bourboule the lowest member of this series is a pumice-bearing sediment which is the equivalent of that at a similar horizon at Lac Chambon yielding a Lower Pliocene flora.

3. COULÉES DES PLATEAUX. The *cinérites* are capped by thick flows of trachytes and andesites of Lower Pliocene age, and these in turn by basalts of Upper Pliocene age. The centres from which these were erupted include the Pic du Sancy, l'Aiguiller and the Banne d'Ordanche. After the main lava activity there was established a Peléean regime in the volcano which gave rise to numerous trachytic domes as well as to the phonolites of Sanadoire and Tuillière.

In the east of the massif lies the volcano of Tartaret, the most southerly centre of activity connected with the Chaîne des Puys. It was initiated in Quaternary times across the valley of the Couze Chambon, blocked the valley to form Lac Chambon and from it basalt-flows spread 25 km. down the valley.

(iii) *Cantal*. The Cantal massif is similar to the Mont Dore but is much bigger, having a diameter of about 70 km. and attaining a height of about 5850 ft. in the Plomb du Cantal. The Puy Mary, Puy Griou and the Puy de Chavaroche are all over 5000 ft.

There were three main phases of activity:

3. *Coulées des Plateaux*—Pliocene.
2. *Brèche andésitique*—Pliocene.
1. *Coulées et Cinérites*—Miocene.

1. COULÉES ET CINÉRITES. The earliest activity was the emission of thick flows of basalts, andesites, trachytes and phonolites which thus form the base of the cone and rest either on the Oligocene deposits or on the crystalline basement. At the Puy Courny, near Aurillac, channels in basalt-flows resting on Oligocene beds and interstratified with sands yielding an Upper Miocene vertebrate fauna including *Hipparion gracile*, are filled with *brèche andésitique*. On the eastern edge of the massif similar basalt-flows are interbedded with *cinérites*, sandstones and clays yielding a Miocene fauna and flora. In the centre of the massif the trachyte of Thiezac, which is considered to be Miocene, is found below the *brèche andésitique*.

2. BRÈCHE ANDÉSITIQUE. The formation of the cone really began in the Pliocene when great thicknesses of *brèche andésitique*, a rock type similar to the *cinérites à blocs* of the Mont Dore, were deposited, the name deriving from the predominant andesitic blocks which attain considerable size in the centre of the massif. The Cirque de Mandailles and the Cirque des

Gardes, on either side of the Griou and being part of the calderas of the former volcanoes Albert Gaudry and Saporta respectively, are thought to have been the centres from which the *brèche andésitique* was ejected. Plant and vertebrate remains from the interbedded *cinérites* show the breccia to be of Lower and Upper Pliocene age, i.e. the explosive phase lasted longer than in the Mont Dore. Andesite- and basalt-flows are interbedded with the breccia and the latter is cut, particularly in the centre of the massif, by dykes of phonolite, trachyte, andesite and basalt.

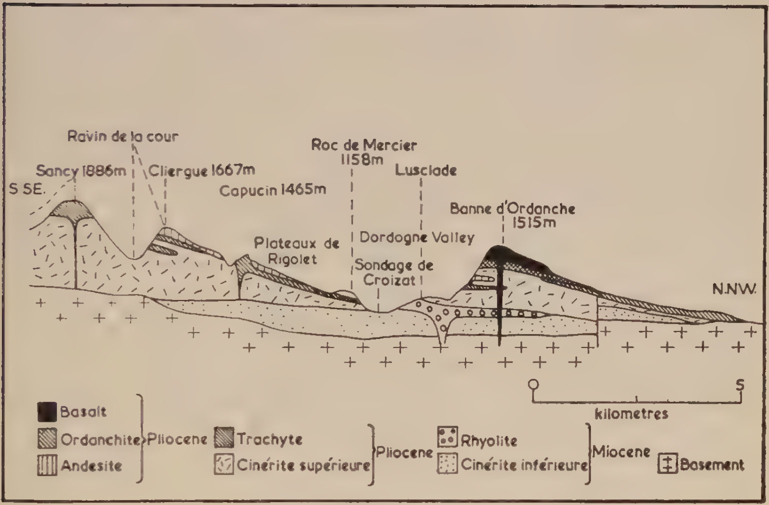


Fig. 4. Section across the Mont Dore Massif

3. COULÉES DES PLATEAUX. The fragmental-ejected rocks are capped by flows predominantly andesitic (from the Puy Mary and Puy de Batailloux), but with some trachy-phonolites (Puy Griou) and some basalts (Plomb du Cantal). On the edge of the massif basalts of the very latest phase of activity, from volcanoes such as Puy Gros and Puy Violent, rest directly on the *brèche andésitique*.

(iv) *Aubrac*. Hawaiian type of activity seems to have characterised this massif. There was quiet emission of lavas with no explosive activity of any kind. The lavas rest on the Margeride granite and the crystalline series of the Lot.

(e) **Quaternary Volcanics.**

The Chaîne des Puys. This N.–S. trending belt comprising about sixty volcanoes is located on a set of NNE. or NNW. fractures in the granitic basement and stretches in a line 35 km. long from the Gour de Tazenat in the north to the Puy de Montenard in the south.

The earliest eruptions were from the Peléean type trachytic volcanoes without craters typified by the Puy-de-Dôme. Puy Chopine, Clierzou and Sarcoui are further examples of this type. The very viscous lava formed high domes or tholoids which grew, onion-like, by succeeding intrusions into the core of the already solidified 'plug', and rarely did lavas flow down the sides of the dome. The central core received protection from the mass

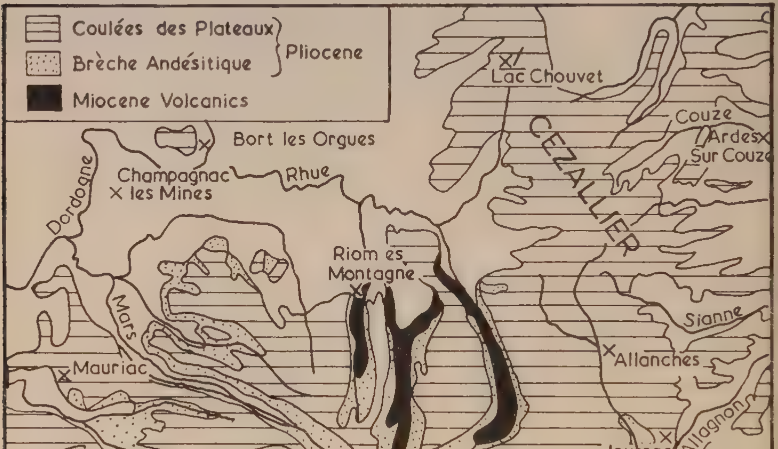


Fig. 5. Geological map of the Cantal Massif

of débris which broke off the ascending 'plug' and fell down the sides of the dome.

Later in the Late Quaternary there was activity of both Vulcanian and Strombolian type when andesites and basalts were extruded and these are typified by the twin volcanoes of Vache and Lassolas, by the Petit Puy-de-Dôme and the Puy Pariou. The cones are formed by a mass of stratified cinders around a central crater which is sometimes breached. Lavas, erupted from the base of the cone, flowed down into the valleys leading into the Limagne or westwards into La Sioule.

Gravenoire, which is a big cinder cone, is located on the western boundary fault of the Limagne.

These Quaternary eruptions can be dated fairly accurately. The oldest flows rest on alluvial terraces of the Middle Quaternary and are between 30–60 ft. above the present level of the valley-floors. The basalts from Lassolas and Tartaret flow more or less along the present valley-bottoms, and at Neschers the end of the flow from Tartaret channels an alluvium deposit containing reindeer remains. '*Ainsi*', says Jung, '*l'homme paléolithique auroit encore vu les dernières manifestations de la chaînes des Puys*.'

2. DAILY ITINERARY

The main party of twenty-five members left Victoria by the early boat train on the morning of Saturday, 8 September, and, travelling by way of Newhaven, Dieppe and Paris, reached Clermont Ferrand at 6 a.m. on the following day. Professor Roques, M. Michel and M. Peterlongo were at the station to welcome them and to conduct them to the Grand Hotel, which was to be the Headquarters for the first week of the excursion. Sunday was spent in various ways, becoming acquainted with Clermont Ferrand and gathering together those members of the party who had travelled individually.

Monday, 10 September

Oligocene and Miocene sediments and volcanics of the Limagne. In the morning the party with Professor Roques, M. Michel and M. Peterlongo travelled by coach westwards from Clermont Ferrand to Puy Chatteix above Royat for a general view of the area. In the far distance to the east are the granitic hills of Forez; nearer is the plain of the Limagne broken by a great variety of small hills and plateaux. These include the Plateau de Gergovie made up of Stampian limestones capped by lava-flows of Miocene age; Montaudoux—a basalt dyke; Puy de Crouël—an Oligocene volcano; Plateau de Beaumont—capped by early Quaternary lavas. The Tiretaine valley, extending eastwards through Royat, is floored with late Quaternary lavas. To the west of Chatteix lies the granitic basement supporting the Chaîne des Puys; to the north is the trace of the

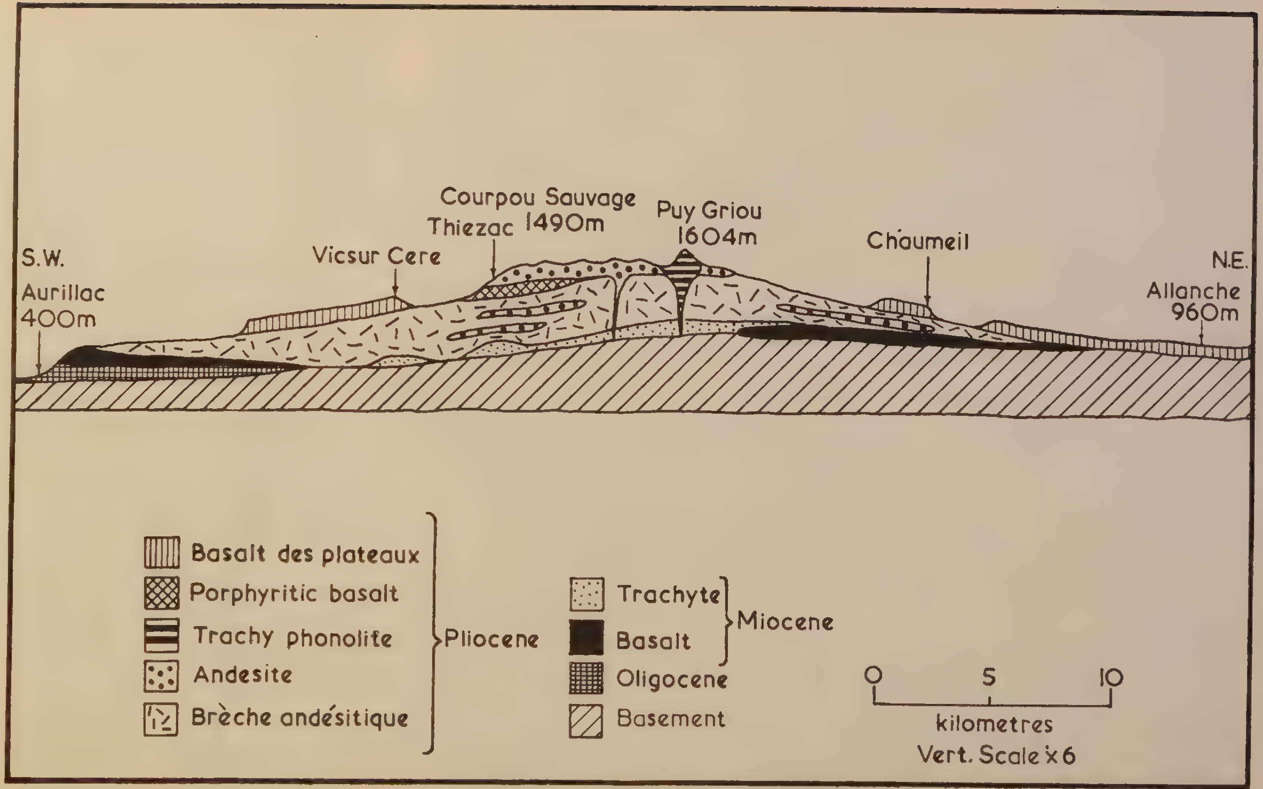


Fig. 6. NE.–SW. Section across the Cantal

western boundary fault of the Limagne; to the south is the volcano of Gravenoire located on the boundary fault.

Here Professor Roques gave an introductory talk on the geology of the Auvergne and outlined the programme to be followed.

In the large quarry at Puy Chatteix the party examined steeply dipping Lower Stampian arkoses close to the fault which throws the Oligocene against the granitic basement to the west. At Chamalières these same arkoses are impregnated with bitumen.

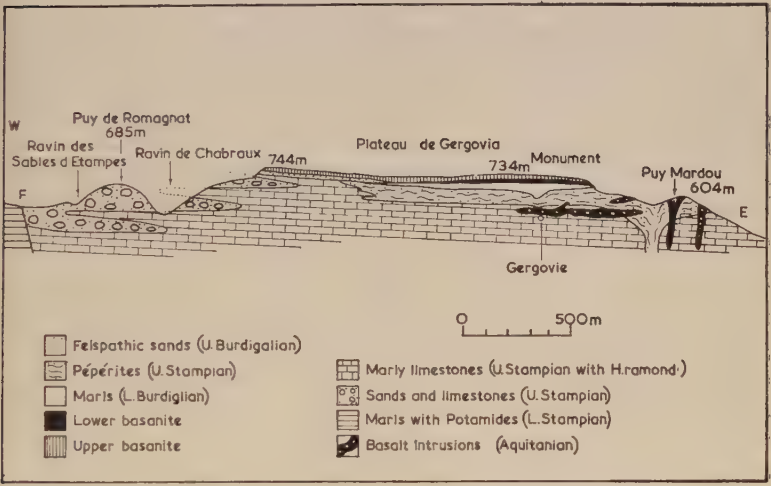


Fig. 7. Section across the south slope of the Plateau de Gergovie (After R. Michel)

The rest of the day was spent in a study of the Plateau de Gergovie beginning with a traverse across its eastern flank. The lowest beds exposed in the large quarries are marls and marly limestones with *Helix ramondi* and vertebrate remains of Upper Stampian age. Above these are *pépérites* which in the south are fairly well stratified, but the stratification is lost as the beds are traced northwards towards the probable centre of eruption. An olivine basalt sill cuts the limestones and the *pépérites* and, at the Puy Mardou, there are two dykes of similar material. A few hundred yards to the west of the monument the *pépérites* are channelled by an old river-valley which is now filled with Burdigalian greenish marls rich in illite and containing plant-impressions. Near the monument the plateau is capped by two flows of analcite basanite which are here in contact.

During lunch, which was taken on the steps of the monument to Vercingetorix, Professor Roques told the story of this local and national hero, his fight with the Roman legions in the area and the subsequent controversy as to whether the battle took place on the Plateau de Gergovie or on the Côtes de Clermont.

In the afternoon the party traversed the western slopes of the plateau and above the Ravin de Chabraux studied the felspathic sands intercalated between the two basanite flows. Farther to the west at the Puy de Romagnat were seen sandy and concretionary limestone facies of the Upper Stampian.

The Rector of the University, the Dean of the Faculty and other Professors were present in the Department of Geology at the *vin d'honneur* kindly given by the Faculty of Science of the University to the members of the party. The Rector and the Dean both gave a warm welcome to the Association on this their second visit to the Auvergne—a period of almost fifty years having elapsed since the first visit in 1902. In the regrettable absence, through illness, of the President, Mr. T. Eastwood, the thanks of the Association for the very generous hospitality were voiced by Dr. R. W. Pocock, the Treasurer, and Ald. W. P. D. Stebbing, a past-President.

Tuesday, 11 September

Oligocene of the Limagne. The first locality visited was the Puy de Crouël, which was reached via R.N. 89 running east from Clermont Ferrand. Here several marly horizons occur in a thick series of *pépérites* which are more angular and fresher than those at Gergovie. In places the stratification is horizontal but generally the dips are fairly steep and there seems to be an inwards dip of 60° all round the small hill suggesting that the *pépérites* fill a neck which was the feeder for the local *pépérites*.

The route continued along R.N. 89 as far as Dallet on the left bank of the Allier where asphaltic limestones of Upper Stampian age are mined. Limestones and marls with *H. ramondi* and interbedded stratified *pépérites* make up the rest of the succession. The asphaltic horizon is formed of large concretionary masses (*calcaires en choux fleurs*) often 30 ft. across and it rests on a good marker horizon of *Cypris*-bearing chocolate coloured limestone. The workings have exposed a funnel-shaped explosion-vent about 250 ft. in diameter filled with débris of the country rock but with no volcanic fragments. The margins of the vent are very sharp and well defined.

After lunch, which was taken on the banks of the Allier, the coach followed the right bank of the river up to Sainte Marguerite at the foot of the Puy St. Romain and in the road cuttings the party examined shales and sands of the Lower Stampian. Above St. Romain are found gypsiferous marls, oil-bearing sands, coccolith beds and limestones of a lagoonal facies of the Lower Stampian. These beds are well exposed in the several quarries in the area and above them are found the harder cherty limestones of the

Middle Stampian. Farther downstream, near Mirefleurs, is the ravine of Fa which is cut into a *pépérite* horizon of the Stampian. Some of the lava blocks found in the *pépérites* are not known elsewhere in the Oligocene.

On the way back from Fa to Mirefleurs by way of Chalendrat, concretionary limestones and chalcedony- and opal-bearing limestones of the Middle Stampian were examined. The return to Clermont Ferrand was via Cournon.

Wednesday, 12 September

Devonian—Dinantian of the Sichon Valley. A long coach journey along R.N. 9 and 9a over Middle Stampian marls brought the party from Clermont Ferrand via Aigueperse, Vichy and Cusset to the valley of the Sichon. In the large quarries at Grivats, Upper Viséan stratified anthracitic tuffs with thin conglomeratic bands are cut by an intrusive quartz-porphyry with large and abundant felspar phenocrysts. A road-cutting about half a mile downstream from Ardoisière gives a good section in the shales, sandstones, conglomerates and *Endothyra*-bearing limestones of the Middle Viséan.

From Pont du Sichon the party walked up the forest road towards Vaux and, in a roadside section above the old lime kilns, examined greywackes (here decalcified, sandy shales) containing *Productus cora*, *P. hemisphaericus*, *Spirifer bisulcatus* and *Phillipsia eichwaldi* of the Middle Viséan. This is one of the many localities visited by Murchison during his travels in Europe. Farther along the road are exposed beds of Upper Viséan age with *P. giganteus* and *P. latissimus*.

At Ardoisière, Middle Viséan rocks are faulted against well-cleaved black slates with plant débris which indicate a Tournaisian age. Traced towards Gué Chervais the slates become more sandy and conglomeratic and furthermore become somewhat hornfelsed because of the nearby coarse-grained biotite granite, which is exposed in the quarry at Moulin Chavan where it cuts sharply across spotted slates with well-developed cordierite. Above Moulin Chavan the road crosses the granitic plateau separating the basins of Ardoisière and Ferrières.

The latter basin shows the more complete sequence but its rocks are all metamorphosed by the post-Viséan granite of Mayet-de-Montagne. In the quarry, a quarter of a mile below the village of Ferrières, Middle Viséan limestones and marls can be seen to have been hornfelsed with the development of diopside and garnets, while the limestone in the village itself yields only calcite. Above Ferrières the black Tournaisian slates have become nodular and cordierite bearing. Porphyritic andesites and andesitic tuffs have given rise to green hornblende and garnet-bearing hornfelses at Matichard and the Rocher de Saint Vincent.

From St. Vincent the coach headed back to Clermont Ferrand, crossing the granitic hills of the Bois Noirs and following the magnificent gorges of the Durolle to Thiers where there was a short halt for tea. Thiers commands a striking view of the Limagne to the west and with the help of a well-sited *table d'orientation* it is possible to identify all prominent features as far away as the Mont Dore.

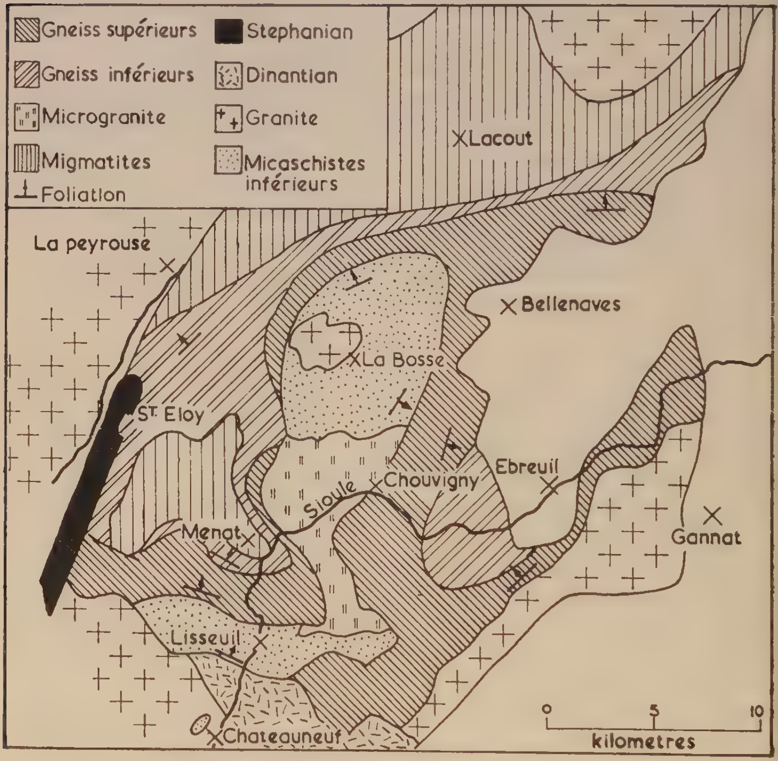


Fig. 8. Geological sketch map of the La Sioule Series

Thursday, 13 September

Crystalline series of La Sioule. Another long coach journey began the day's proceedings, this time along N. 9 and G.C. 27 through Riom and Châtel Guyon, where the road crosses the western boundary fault of the Limagne onto the granitic basement. A short diversion was made to the Gour de Tazenat, a beautiful lake in the crater of a volcano which was the most northerly manifestation of the Quaternary activity of the Chaîne des Puys. The road from Manzat to Châteauneuf-les-bains suddenly dominates the very deep valley of the Sioule, and from the Cross by the roadside there is a most impressive view to the north-west. The river is entrenched in deep, incised meanders with cliffs two or three hundred feet high cut in a fine grained granite which is capped at Vignoles by Viséan tuffs.

From the Cross the road descends steeply to Châteauneuf in the bottom of the valley, where the coach turned north to enable the party to study the crystalline series as far as Pont de Menat. Lunch was taken by the river at Pont sur la Sioule after most members had been ferried across to examine anthracitic tuffs of Viséan age which are faulted against granitic rocks of the basement.

The foliation in this area of crystalline rocks has a steady dip to the NNE. and a northerly traverse from Lisseuil to Pont de Menat showed the following succession:

Rocks	Zone	Locality
Biotite-schists with quartz-amygdales	*Micaschistes inférieurs*	1 km. either side of Lisseuil
Muscovite-biotite-gneiss	*Gneiss supérieurs*	1 km. north of Lisseuil to ½ km. south of Château Rocher
Biotite-sillimanite-gneiss	*Gneiss inférieurs*	Château Rocher to Pont de Menat

At the western end of the Pont de Menat are exposed the *anatexites* from the core of the inverted anticline. In hand specimen the foliation is sufficiently uniform to warrant the term *embrechites*, but considered over the whole outcrop the foliation is swirly and thus the rocks are *anatexites*.

The quarry in Oligocene bituminous paper shales at Menat proved to be very fossiliferous and one particularly fine fish was found by a member of the group.

The Sioule river was followed from Pont de Menat through Chouvigny to Ebreuil and for much of the way the river flows through deep and narrow gorges of which the best known are at Chouvigny, where the cliffs are cut in the laccolithic porphyritic granite of Pouzol.

The return to Clermont Ferrand was by way of Gannat, Aigueperse and Riom.

Friday, 14 September

Chaîne des Puys. The first locality visited was the large quarry just to the east of Boisséjour on the road from Clermont Ferrand through Beaumont. Here is exposed part of the fissure system of the Mont Poly volcano and the basalt of this eruption has caught up Oligocene marls and changed them into hard porcellanites. The lavas flowed down the valley past Beaumont and Aubière and they rest on beds of Monastirian age while

Flandrian fossils have been found in fissures in the top of the flow. It was thought formerly that the Beaumont flow emanated from Gravenoire, but a break can be demonstrated east of Boisséjour and the Beaumont flow shown to be from Mont Poly.

Large quarries have been opened in the Strombolian type volcano of Gravenoire and give a good cross-section of this Quaternary cone. The scoriaceous material which dips outwards at about 30° contains large volcanic bombs, several good specimens being collected. The composition of the débris has been shown to be the same as that of the flow which issues from the base of the cone towards Boisséjour.

From Gravenoire the coach went via Royat to the Pont des Soupirs in the valley of the Tiretaine. Basalt flows from the Petit Puy-de-Dôme followed this valley which is cut into the granitic basement. In the course of prospecting for water at Pont des Soupirs it has been shown that there were two flows with an alluvial horizon between.

At the small quarry of Chuquet-Gensetoux ejected blocks of granite and granite gneiss with vitrified margins are found in volcanic débris which contains many good crystals of augite.

The 1902 party made the ascent of the Puy-de-Dôme 'easily on foot in less than an hour'. This time the ascent was much quicker and no stop was made after leaving the Col de Ceyssat. Here were found blocks of hornblende domite which were ejected during the last phase of activity of the Puy-de-Dôme and the neighbouring Puy Lacroix. This domite forms the outer mantle of the Puy-de-Dôme whose core is made up of massive biotite-domite in the form of a plug surrounded by a breccia derived contemporaneously as the successive biotitic intrusions pushed into the central plug. This biotite-domite was examined in road cuttings on the descent.

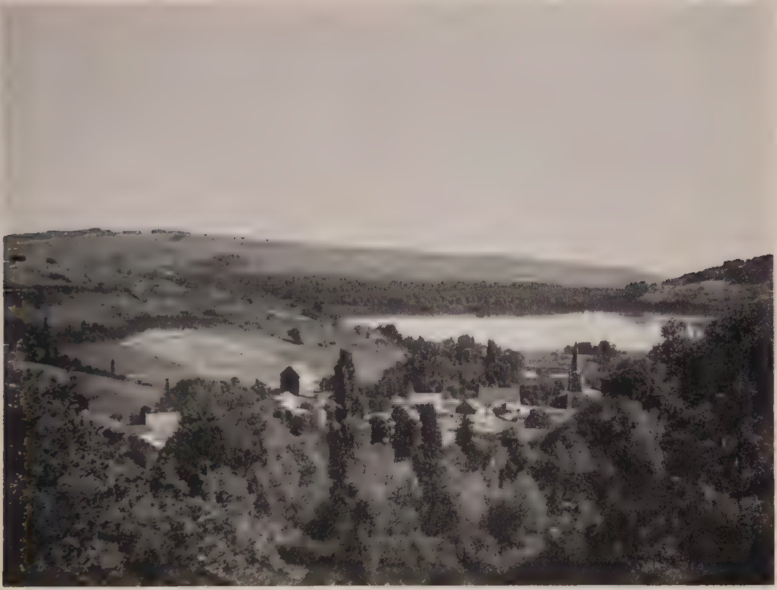
The view from the summit was very fine indeed and once again identification of the surroundings was facilitated by a *table d'orientation*. To the north and south stretch the lines of Quaternary volcanoes; to the east is Clermont Ferrand and the Limagne; while away to the south-south-west lies the volcanic massif of the Mont Dore.

After a brief inspection of the ruins of the Temple of Mercury lunch was taken just below the summit of the Puy with a fine view of the chain of volcanoes to the south.

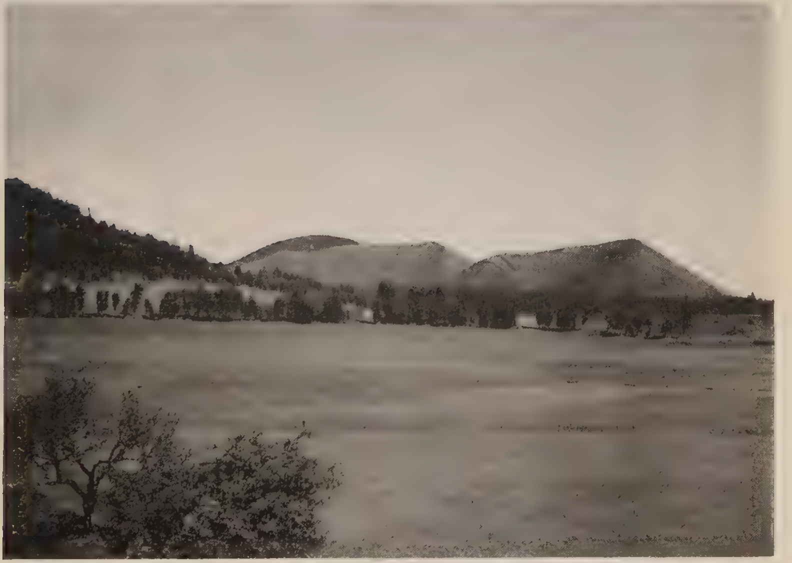
In the afternoon most members of the party descended on foot the northern slopes of the Puy-de-Dôme past Nid de la Poule, the perfectly preserved crater of the Petit Puy-de-Dôme, to the double crater of the andesitic volcano of Pariou with andesite dykes intrusive into the cone.

From the foot of Pariou the return to Clermont Ferrand was along R.N. 141 B across the 'cheire', the broken rubbly top of one of the lavas from Pariou.

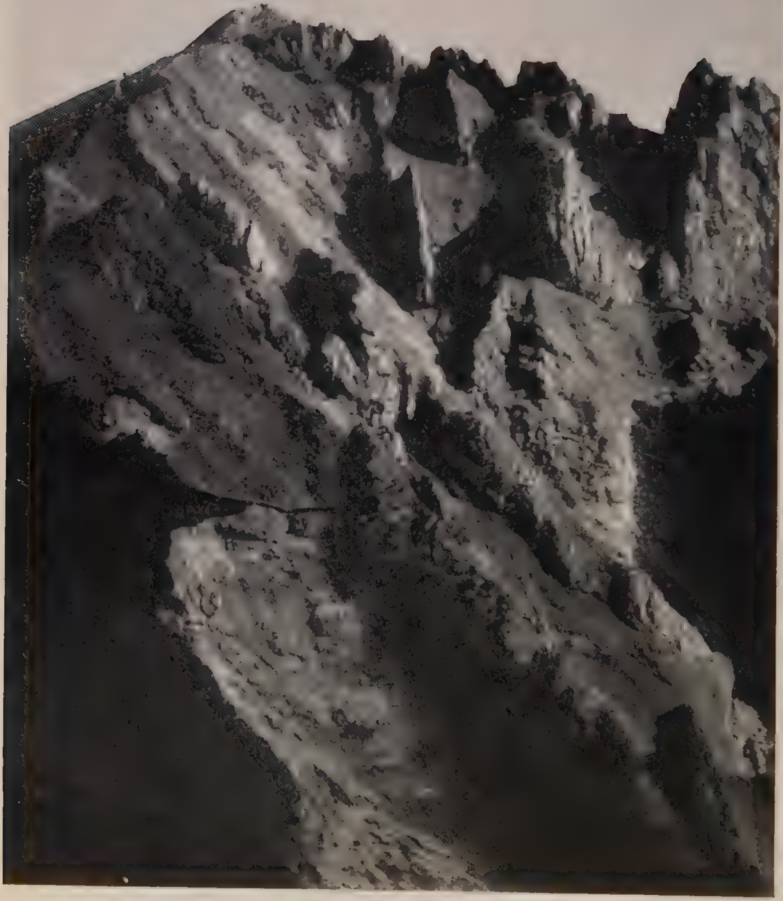
In the evening members of the Association had the great pleasure of



Lac d'Aydat dammed by lava flow from Puy de Lassolas and Puy de la Vache



Puy de Lassolas and Puy de la Vache. Breached cones at the south end of the chain of Puys



Pic de Sancy. Dykes of trachyte (Sancyite) in Cinérite à blocs being entertained to a *vin d'honneur* by the Rector of the University and his wife. Dr. R. W. Pocock and Alderman W. P. D. Stebbing replied to the Rector's speech of welcome and thanked him for his gracious hospitality.

Later, the same evening, the members of the party were very pleased to entertain Professor Roques, Mme. and M. R. Michel, M. Peterlongo and M. Lavarenne to dinner at the Grand Hotel.

Saturday, 15 September

Vulcanicity of the Mont Dore. This day was the beginning of the tour of the south of Auvergne and the headquarters for the next two days was to be La Bourboule. The party, with Professor Roques now as sole director, left Clermont Ferrand by coach on R.N. 89 through Ceyrat. At Saulzet-le-Choud a brecciated younger granite with large decomposed felspars shows the presence of the western boundary of the Limagne.

The one-man quarry at Fontfreyde is in a trachy-andesite being the second of the two flows to issue from the Puy de Mercoeur away to the west.

The road follows quite closely the boundary between this flow to the north and the granite basement to the south.

After passing through La Cassière tunnel a slight diversion to the west was made to visit the twin volcanoes of La Vache and Lassolas, both of which are breached cones. The now wooded lavas from these centres followed the valley of the Veyre eastwards as far as St. Amand and in so doing blocked two tributary valleys in which water was impounded to give the lakes of a Cassière and Aydat. G.C. 13 runs on the excellently developed 'cheire' of this flow, as far as the crossroads three kilometres east of Verneuze.

The road southwards from Aydat leads on to the plateau of Murols, and from Moulin de Laval the party had a magnificent view of the volcanic massif of the Mont Dore to the west. The plateau-surface, which is flat and grass covered, is formed of lava-flows which rise steadily as they are traced westwards. The first of these basalt flows from the Mont Dore was encountered at Moulin de Laval and this and the vertical basaltic dykes of Murols—intruded into Oligocene sediments—both show well-marked prismatic jointing, which is vertical in the former and horizontal in the latter. On one of these basalt dykes is built the thirteenth century Château de Murols, which commands the approaches of three important routes. Near the town of Murols, Oligocene sands can be seen filling an old valley which had been cut into the basalt-flows.

Lunch was taken on the shores of Lac Chambon which was formed when the volcano of Tartaret erupted during the Quaternary and blocked the valley of the Couze Chambon. The volcanic ashes from Tartaret rest on *cinérites* with interbedded pumice horizons which are here the earliest manifestations of the Mont Dore activity. The *cinérites* have yielded a rich Lower Pliocene flora.

From Chambon to the Col de Diane the road follows over granitic basement and then over the coarsely blocky *Upper Cinérites* which, near the col, are cut by numerous trachyte dykes and are covered by flows also of trachytic nature. At the Col de Diane R.N. 683, towards Randanne, was followed and a little beyond the Lac de Guéry the head of the deeply glaciated valley of Le Sioulet, cut into *cinérites*, was reached. Dominating the head of the valley are the isolated masses of Tuilière and Sanadoire which are formed of a hauyne-bearing trachy-phonolite. Sanadoire is the neck of the volcano and has radiating prismatic jointing whereas Tuilière is part of the flow emanating from it and has vertical prismatic jointing.

On the journey from here to La Bourboule via Mont Dore the party was able to study a good selection of the rock types of the area in quarries and road cuttings. These types included doreite at Mignole, a kilometre east of Mont Dore; *cinérites à blocs* in the road cuttings on the northern bank of the Dordogne; nosean phonolite interbedded with Lower Miocene *cinérites* at Pessy; rhyolitic breccias and rhyolite flows at Lusclade.

In La Bourboule itself, a fault, letting down Miocene *cinérites* and arkoses, containing large granitic fragments, against the granitic basement, was studied in the courtyard of the buildings connected with the spring of Choussy.

Sunday, 16 September

La Bourboule is renowned both for the medicinal value of its warm natural mineral waters and as a holiday centre, and the members of the party were able to make a brief tour of the town in the early part of the morning. Afterwards they were the guests at a *vin d'honneur* most kindly given by the Mayor who unfortunately was unable to be present. The Deputy Mayor warmly welcomed the party and Alderman W. P. D. Stebbing and Professor J. A. Steers replied suitably. Following the *vin d'honneur*, the party was taken on a conducted tour of the *Etablissement des Grands Thermes*, where they were able to inspect the very varied facilities provided for the treatment of many types of respiratory and skin diseases. The visit was concluded in the main hall of the building where each member was invited to partake of the waters, rich in arsenic!

Thus refreshed, the party set out in the afternoon for a trip to the Puy de Sancy along R.N. 496 and traversed a section (shown in Fig. 4).

The ascent of Sancy was made the easy way in the *téléférique* though there was still a good climb from the top station to the summit. The main mass of the hill is *cinérites à blocs*, but this is cut by numerous trachyte (sancyite) dykes which are more resistant to weathering than the *cinérites* and thus form vertical or sub-vertical walls standing up many feet above

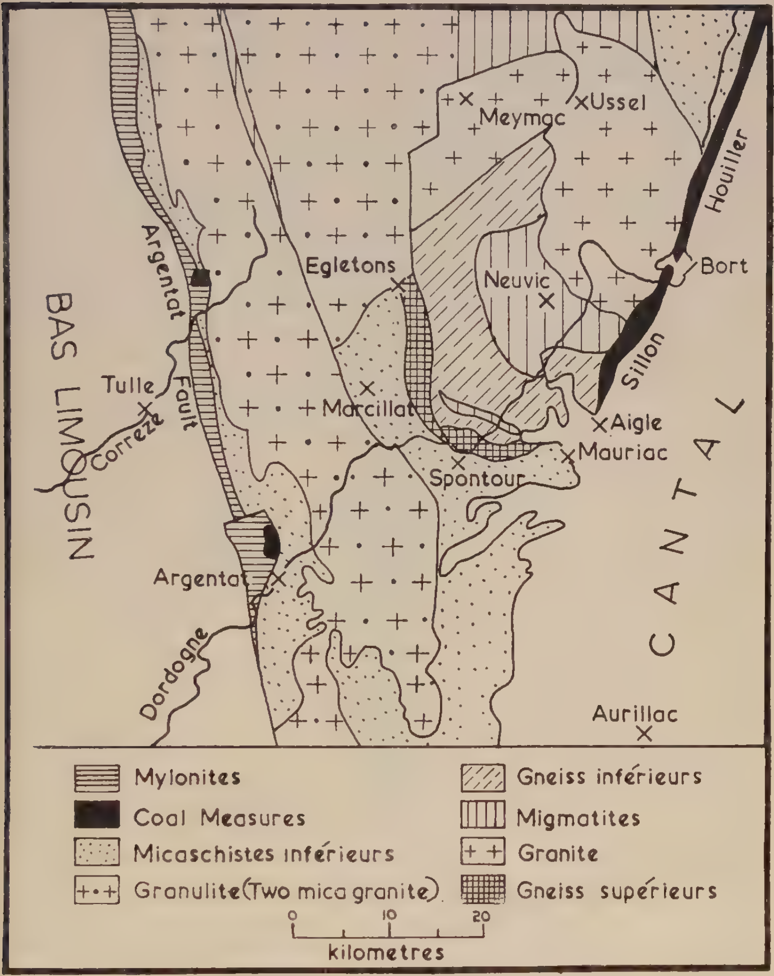


Fig. 9. Sketch map of the Millevaches Plateau and the Dordogne Massif

the country rock. These dykes are well seen from the *téléférique*, the upper station of which is built on one of them. The peak of Sancy, made up of a sancyite dyke, commands a magnificent view of the whole of the Mont Dore massif, the Chaîne des Puys to the north-east and the massif of the Cantal to the south. There was unfortunately a certain amount of low cloud which obscured the promised view of the distant Alpes de Dauphiné.

Most people made the steep descent on foot and were able to examine the deeply eroded gullies and also the ski runs used during the winter sports season.

After tea, in a café at the foot of the mountain, the return was made to La Bourboule.

Monday, 17 September

In view of the long journey to Brive an early start was made along R.N. 122 and then R.N. 89 via Eygurande to Ussel. To the south-west of Ussel, quite near to the main road to Tulle, a series of quarries shows the contact between the Ussel and Meymac granites. Professor Roques indicated the main features of these post-tectonic masses, the Meymac granite, 'porphyritic' with biotite and tourmaline, being later than the Ussel which is a fine-grained biotite-bearing calc-alkaline type having a tourmalinised margin. The contact, though irregular, is sharp; isolated felspar porphyroblasts of Meymac type are found in the Ussel granite several yards from the contact.

From the quarries to Neuvic, via R.N. 89, 679 and 682, the road crosses the Ussel granite massif and it is only south of Neuvic on the Mauriac road that the section in the crystalline series of the Middle Dordogne is begun. The series is isoclinal and has been overturned as the upper zones of the sequence can be seen to dip beneath the gneiss and migmatite zones. Only half of the sequence can be seen. The traverse began north of the Pont de St. Projet where migmatites (anatexites with large cordierites) were examined. At the bridge itself biotite-sillimanite gneisses of the *gneiss inférieurs* outcrop on the northern side and *cipolins* of the *gneiss supérieurs* on the south. Here the crystallines are covered by basalt-flows emanating from the Cantal to the south.

The Aigle dam, one of a series built to utilise the water-power of the Dordogne, is built across a narrow part of the valley where a thick lens, a kilometre or so wide, of migmatites (embrechites) occurs within the *gneiss inférieurs*. It was originally intended to follow the Dordogne downstream from l'Aigle to Spontour, crossing both gneiss zones, but the recent closing of the next dam below the Aigle had drowned one or two small villages and flooded the roads and so a long diversion via Chalvignac was necessary.

The road to Marcillac crosses and recrosses both the gneiss zones and the migmatites and reaches *micaschistes inférieurs* near La Croisille. The schists dip beneath the much folded and contorted gneisses.

Mylonites along the Argentat fault were studied in a roadside section eight kilometres from Tulle.

When the party reached Brive they were introduced to Dr. P. Lapadu Hargues who was to assist Professor Roques and later take over direction of the excursion.

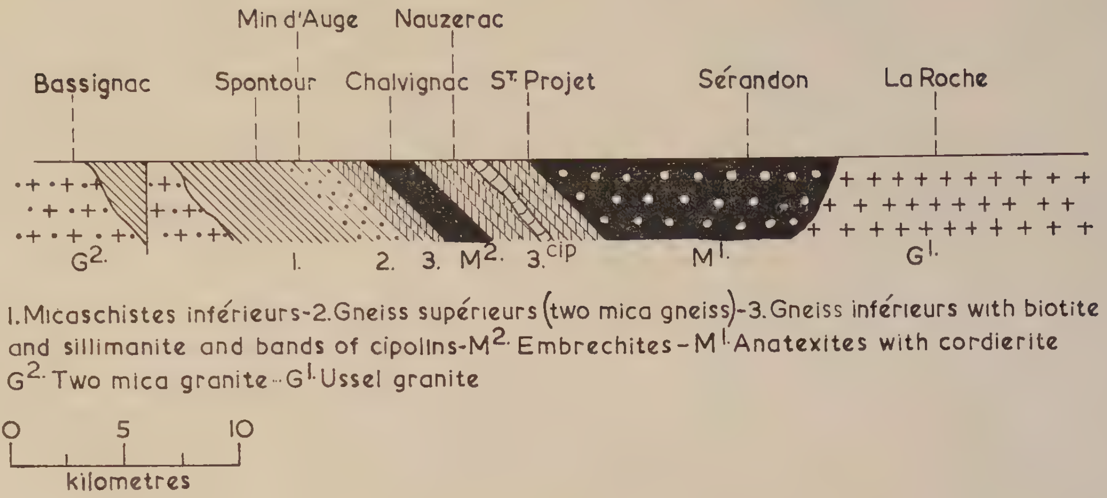

Min d'Auge
Nauzerac
Bassignac
Spontour
Chalvignac
S^T. Projet
Sérandon
La Roche
G2.
1.
2.
3.
M2.
3.cip
M1.
G1.
1. Micaschistes inférieurs - 2. Gneiss supérieurs (two mica gneiss) - 3. Gneiss inférieurs with biotite and sillimanite and bands of cipolins - M2. Embrechites - M1. Anatexites with cordierite
G2. Two mica granite - G1. Ussel granite
0
5
10
kilometres

Fig. 10. Section across the Middle Dordogne

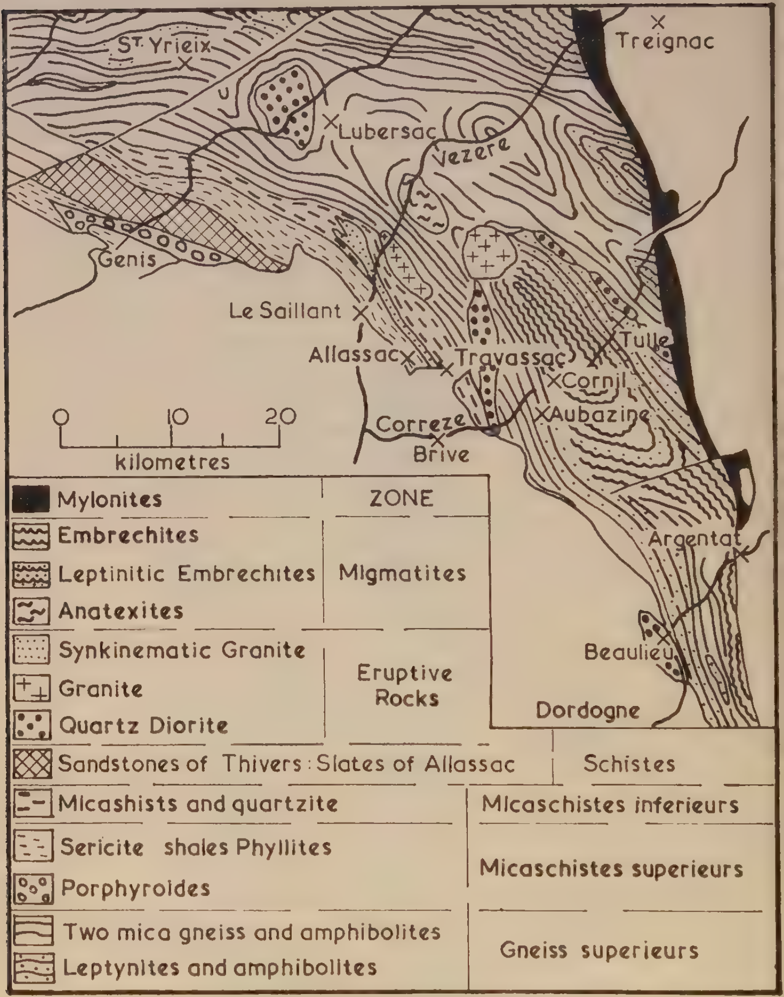


Fig. 11. Sketch map of the Bas Limousin

Tuesday, 18 September

The examination of the crystalline series of the Bas Limousin was begun at Allassac which was reached via Donzenac after a traverse across gently undulating country floored by flat-lying red micaceous sandstones of Permian age.

Near the station at Allassac steeply dipping quartz-rich slates are worked in big quarries. The slates are unmetamorphosed, with perfect parallelism of cleavage and bedding, and they are found on the extreme western flank of the Tulle anticline. The rocks are unfossiliferous but it is considered probable that they are of Cambro-Silurian age. Metamorphism increases to the north-east and a few hundred yards north of Allassac slightly metamorphosed greywackes and sericite-bearing shales are exposed in the roadside.

From the small village of Le Saillant the party walked up the valley of the Vézère to the Saut du Saumon dam, which is built on a small laccolithic mass of granite intruded into sericite and chloritic slates and quartzites similar to those of Allassac. The Saut du Saumon granite is syntectonic and possesses a very well-marked and regular schistosity.

Sandstones and conglomerates of Stephanian age filling an old Carboniferous valley were studied between Donzenac and Travassac. In the latter village very deep, narrow quarries have been excavated in sub-vertical quartz- and biotite-rich slates belonging to the *micaschistes inférieurs*. Rocks of the same zone at Sainte Féréole contain biotite, garnet and large staurolites.

The main road from Brive to Tulle (N. 89) was joined at Malemort and the rest of the day was occupied in a traverse across the Tulle anticline along this road. *Micaschistes inférieurs*, garnetiferous and steeply dipping to the west and similar to those of Sainte Féréole, are exposed at Baroudie. The *micaschistes–gneiss* junction is not exposed in the valley bottom but Professor Roques indicated that higher up the valley sides a laccolithic quartz-diorite has been intruded along the junction though north of the Corrèze valley the diorite transgresses the junction.

The *gneiss supérieurs* are reached at the Papeterie de la Maison Neuve; the pelitic rocks show the characteristic development of two micas and associated with these are bands of amphibolites. Near the station at Aubazine segregation pegmatites are developed.

Below these pelitic gneisses, but still in the same zone, there is a series of leptynites, considered to be metamorphosed acid lava-flows. The upper group, leptynites of Aubazine, which are worked in the quarries of Vergonzac, are fine grained and albitic and have interbedded chlorite-slates rich in calcite. Below these are the pink leptynites of Cabane which are potassic, microcline being the dominant felspar, and very fine grained. The lowest leptynite group, which is sodi-potassic and grey in colour, is exposed near the level crossing just west of Cornil and they are interbedded with a garnetiferous two-mica gneiss. This lowest group is cut by several pegmatite dykes which are held to indicate the nearness of the migmatite front. Gneisses showing the first stages of migmatisation are well exposed in the large quarries of Cornil where they are cut by the laccolithic, post-tectonic, fine grained granite of Cornil. Gneisses pass into migmatites

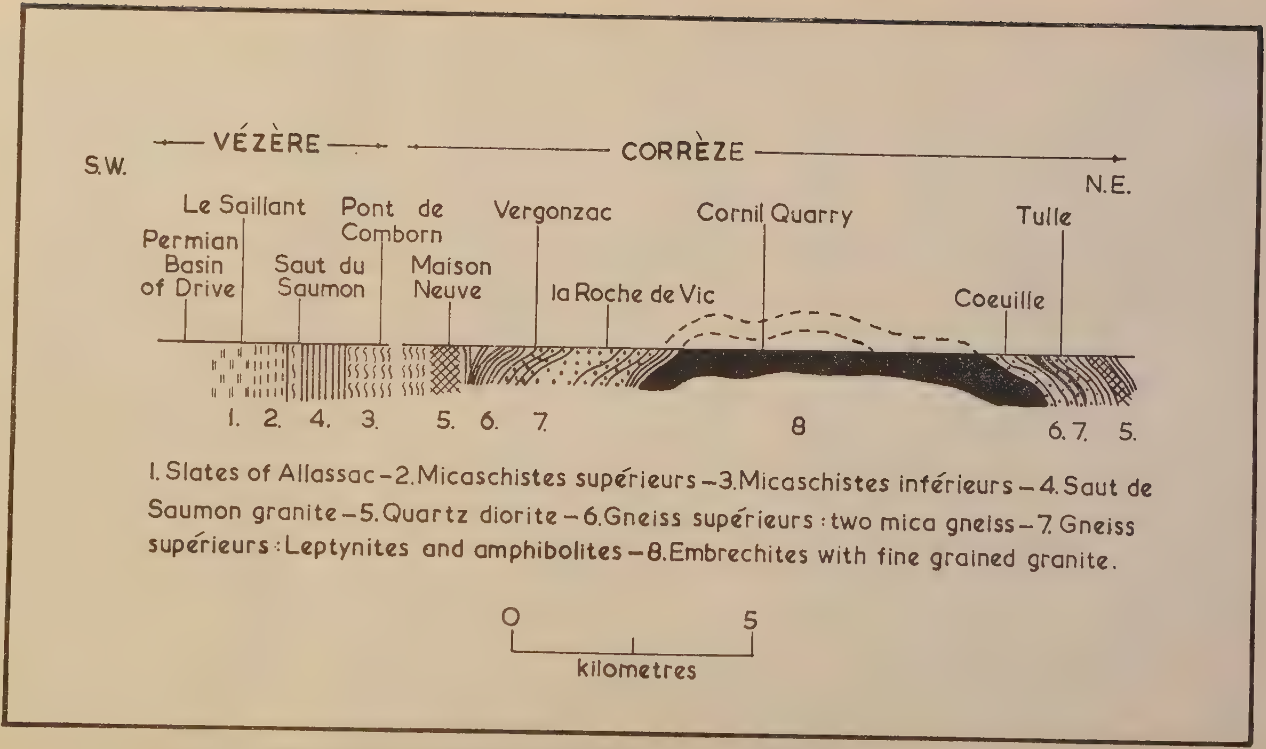

VÉZÈRE
CORRÈZE
S.W.
N.E.
Le Saillant
Permian Basin of Drive
Pont de Comborn
Saut du Saumon
Maison Neuve
Vergonzac
la Roche de Vic
Cornil Quarry
Coeuille
Tulle
1. 2. 4. 3. 5. 6. 7. 8 6. 7. 5.
1. Slates of Allassac – 2. Micaschistes supérieurs – 3. Micaschistes inférieurs – 4. Saut de Saumon granite – 5. Quartz diorite – 6. Gneiss supérieurs : two mica gneiss – 7. Gneiss supérieurs : Leptynites and amphibolites – 8. Embrechites with fine grained granite.
0
5
kilometres

Fig. 12. Section across the Tulle Anticline along the Rivers Vézère and Corrèze

(embrechites) between Cornil and Chameyrat and here the embrechites, very rich in felspar and with large augen, are horizontal, being in the core of the Tulle anticline. They are cut by large intrusions of Cornil granite and by several cross-cutting pegmatites.

The eastern flank of the anticline was followed only as far as Tulle. The grey leptynites of Cornil type have been migmatised and are worked in the quarry at Mulatet; the pink leptynites of Cabane type are exposed in the roadside on the eastern outskirts of Tulle.

The return to Brive was along R.N. 89.

Wednesday, 19 September

Brive was left behind and the road followed was that of N. 680 towards Argentat and Aurillac. From Brive to St. Chamont the road crosses the southern part of the Bas Limousin or Tulle anticline but no stop was made until mid-way between St. Chamont and Argentat, where the Argentat fault throws the crystallines of the Bas Limousin against the massif of the Millevaches. The crush zone along this major dislocation may be up to a mile in width and mylonites are commonly developed. At this point on R.N. 680 it is migmatites (embrechites) which have been crushed but each zone in turn is cut by the fault and is in turn mylonised.

A short stop was made in the picturesque little town of Argentat.

R.N. 120 was followed all the way from Argentat to Aurillac. Few stops were made between Argentat and Montvert but the Director explained that the relations as seen at Sexcles were typical of this part of the Millevaches massif. Here the party examined interdigitation of granulite (two mica granite) and biotite schists. The granulite has a main north–south trend and has varying textures—normal granitic, oriented or migmatitic—and is considered to be syntectonic.

The micaschists are cut by the post-tectonic biotite-granite of Laroquebrou, round which there is developed a thermal aureole with the production of hornfelses.

A short diversion from R.N. 120 was made to visit the new dam at St. Étienne Cantales, which is built on the Laroquebrou granite and impounds the waters of the Cère. R.N. 120 was then followed through Aurillac to Arpajon where large quarries in the Puy de Vaurs give a good section through the Oligocene of the Aurillac basin. The lowest beds are red and mottled clays of Sannoisian and Lower Stampian age which are best exposed in the roadway leading to the quarry. Above these are Middle Stampian white cherty marls with *Hydrobia dubuissoni*, *Potamides lamarcki* and species of *Cypris*, and these in turn are succeeded by the white limestones of the Upper Stampian with *Limnea pachygaster*, *Planorbis cornu* and *Helix arvernensis*. In a part of the Puy de Vaurs, away from the quarry, a thin bed of Pontian sands rests in places on the Upper Stampian limestones but in general these are followed by the *brèche andésitique* which forms a capping to the hill.

In the outskirts of Aurillac along R.N. 126 to Vic-Sur-Cère the quarries of Puy Courny have been opened in Miocene volcanic rocks. The road to the quarry is cut into Sannoisian red and mottled clays and cherty marls of Middle Stampian age. In the quarry itself the basalt rests on white *Potamides*-bearing limestones of the Upper Stampian. The upper surface of the flow has suffered intense pene-contemporaneous weathering to give a reddish clay (*argile rouge equatoriale*). As at the Puy de Vaurs, Pontian sands, which have yielded *Hipparion gracile*, and the *brèche andésitique* rest on the top of the basalt.

In the evening Professor Roques, Dr. Lapadu-Hargues and the members of the party were the guests, at a *vin d'honneur*, of the Mayor and council, the Chamber of Commerce, and prominent citizens of Aurillac, the capital town of the Haute-Auvergne. The Mayor warmly welcomed the Association and presented to each member a well-illustrated guide book to the Cantal. Dr. R. W. Pocock and Alderman W. P. D. Stebbing expressed the thanks of the party to the Mayor for his very cordial reception and hospitality.

Thursday, 20 September

From Aurillac, which is in the valley of the Jordanne, R.N. 126, to Vic and Murat, rises on to a low plateau made up of Oligocene sediments and Miocene basalts and then joins the valley of the Cère, cut into *brèche andésitique*, near Yolet. It was this road that was followed through Vic, famous for its health-giving waters, to Thiézac, which was the first stop. From the small hill of the Vierge de Thiézac, of *brèche andésitique* resting on granite gneiss and Oligocene sediments which are in contact along the fault, the party had a grand view of the U-shaped, deeply glaciated valley of the Cère with its steep rock-step, the Pas de la Cère, small transverse moraines, Miocene trachytic dome and the present river cutting a deep valley into the floor of the original glacial valley. Near the railway station a porphyritic trachytic sill and trachyte and basalt flows, interbedded with *brèche andésitique*, were examined. A similar section is found on the north side of the valley but here there is a capping of Pliocene basalt (*basalte des plateaux*).

From Thiézac the road climbs up the valley of the Cère, past the rock step of the Pas de Compaing, the Puy de Griou, a phonolite dome, and the basaltic Plomb du Cantal (*basalte terminal*) to the Col de Lioran, which is now pierced by a tunnel and which separates the valleys of the Cère and Allagnon. Near the western end of the tunnel andesitic flows and dykes are found within the *brèche andésitique*. Lioran was the centre of Pliocene vulcanicity.

The road into Murat, where the valley of the Allagnon widens considerably, is cut into *brèche andésitique*, which near Murat rests on Lower Miocene basalts and is covered by the *basalte des plateaux*. Dominating the town is the Rocher de Bonnevie, on which has been built a large statue of Notre Dame de la Haute-Auvergne. At Bonnevie, Bredons, on the opposite side of the valley, and several other neighbouring centres, many of them having vertical columnar-jointed basalts, indicate that here was the focal point of the Miocene vulcanicity of the area.

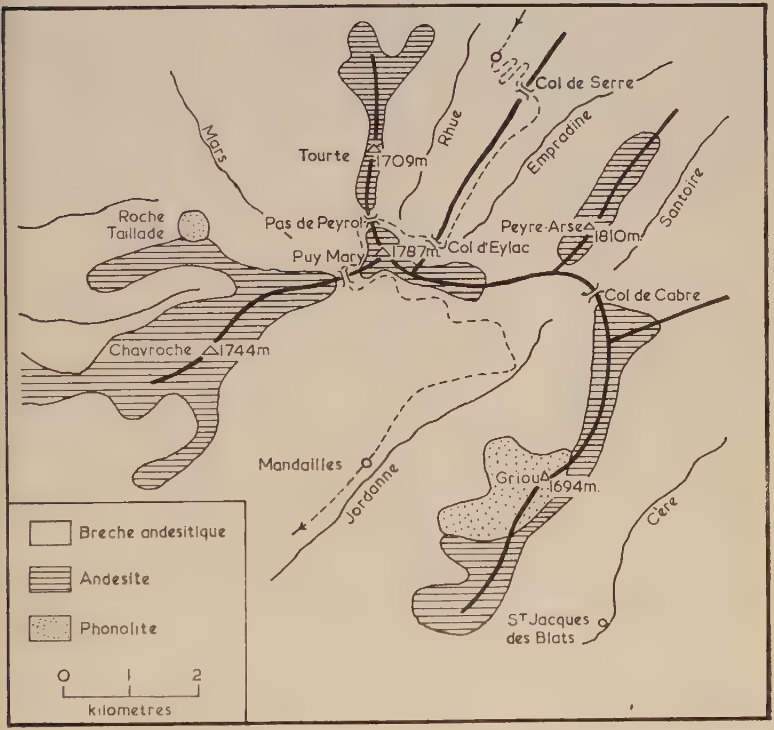


Fig. 13. Crater of the Puy Mary Volcano

The *brèche andésitique* is continually in evidence from Murat to the Col d'Eylac by way of the Col d'Entremont and the valleys of the Santoire and Empradine. The party left the coach at the Pas de Peyrol and climbed the 600 ft. to the summit of the Puy Mary (5800 ft.) where the predominant rock is hornblende andesite. The day was clear and visibility very good and for one brief moment it was possible to see some Alpine peaks many kilometres away to the east. Topographically and scenically the region is very striking. The Puy Mary is a *noeud hydrographique* and from it radiate five deeply glaciated valleys each dominated at its head by a steep cirque. The largest of these, the cirque de Mandailles, at the head of the valley of the Jordanne, is the site of the former Pliocene volcanic crater which has since been broken up by erosion. The andesitic flows from this volcano are now preserved as long tongues along the crests separating the various cirques and forming such hills as the Puy de Chavaroche, Puy Mary and the Puy de Peyre-Arse. The Jordanne Valley was followed back to Aurillac.

Professor Roques was to leave the party early the next morning so a farewell dinner was held in the hotel. Professor K. C. Dunham, on behalf of the party, complimented Professor Roques and his colleagues on the excellent arrangements made for the excursion and thanked him for his admirable leadership. The vote of thanks was wholeheartedly supported by all present. In reply Professor Roques expressed the hope that this brief introduction to the geology of the Auvergne would lead to further visits from members of the Association.

Friday, 21 September

After a short journey along N. 120 from Aurillac to Pont d'Arpajon the coach turned off along N. 590, a very tortuous road leading to Raulhac. The road follows the flanks of several valleys which flow to the south-west from the volcanic massif of the Cantal and which have cut down into the basalts emanating from the Cantal. On one of these isolated blocks of basalt, the Rocher de Carlat, was built a castle to guard the southern approaches of the Haute Auvergne. The castle was razed under the directions of Henry IV and all that now remains is the site and the Escalier de la Reine—steps cut into the basalt and giving access to the castle.

Oligocene sediments, the most southerly of the Aurillac basin, can be seen along the side of the road (N. 600) from Raulhac to Mur de Barrez, where *brèche andésitique* from the Cantal is surmounted by a flow of basalt.

Clays and red sands of the Oligocene of the Brommat basin were examined by the roadside leading from d'Albinhac to the Barrage de Sarrans. The dam is built on a part of the Margeride granite whose western margin is fairly closely followed by the valley of the Truyère. The granite here is 'porphyroide', with very large crystals of 'dents de cheval' microcline. Tongues of basalt from the Aubrac cover the granite between Ste. Genevieve and Laguiole. The southern margin of the post-tectonic Margeride granite, which is reached just south of Laguiole, cuts across the muscovite sericite schists of the *micaschistes supérieurs* and the muscovite biotite schists of the *micaschistes inférieurs*.

The River Lot which runs E.–W. through Mende to Espalion flows approximately along the junction of the basalt-capped crystalline basement to the north and the Mesozoic Causses country to the south. The road eastwards from Espalion closely follows this river valley so that at times it crosses basement as between La Mothe and Les Salleles, where there are hornblendic gneisses and tourmaline-bearing quartzites, and at others it crosses the Permian as below La Mothe, and the Lias upstream from Les Salleles.

The Lot valley was left at Balsièges whence the coach followed N. 107 to Florac, stopping at the Col de Montmirat before the steep descent into the valley of the Tarn and Florac itself. South-westwards from the col lies the Causse de Sauveterre and, beyond it, the Causse de Méjan; south-eastwards is the granite massif of the Mont Lozère with its thin cappings of Liassic sediments. These two very different areas are brought into contact along a series of N.–S. faults which, at the Col de Montmirat, are crossed by a major ESE.–WNW. dislocation which can be traced from Aurillac in the west through Entraygues and the Mont Lozère granite to the Cévennes Méridionales in the east. These faults are members of a series which have strongly broken up the Margeride region and with which may be associated the vulcanism of the Aubrac.

From Montmirat the descent into Florac is over small granite masses and metamorphic rocks of the *micaschistes inférieurs* Zone.

Saturday, 22 September

This day was essentially 'touristique' being concerned with a traverse of fifty kilometres or so of the Tarn gorges. To reach these the party took N. 107 to Faux and here turned on to 107 bis.

At Ispagnac a N.–S. fault throws schists against Upper Lias marls to the west, and from here to Les Vignes, the limit of the traverse, the Tarn flows over Jurassic rocks of varying ages and lithologies. To the north of the river is the Causse de Sauveterre and to the south the Causse de Méjan. The rocks in the floor of the valley from Ispagnac to Sainte Enimie are Middle Jurassic dolomites with cliffs of Upper Jurassic dolomites and limestones. The majesty and awe-inspiring nature of the gorges made a deep impression on the whole party. Cliffs hundreds of feet high in places overhang the road which at times has to be tunnelled into the rock, so narrow is the valley bottom.

The trend of the river-valley is controlled by N.–S. fractures between Sainte Enimie and Saint Chély, and between the Cirque des Baumes and Peyreleau, whereas from St. Chély to the Cirque the valley is E.–W. and follows Upper Bathonian and sometimes Lusitanian limestones. Several sight-seeing stops were made along the valley.

The coach turned off to the east at Les Vignes and climbed up the narrow, steep road (G.C. 16) with several hairpin bends cut into the eastern flank of the valley. From here the road back to Florac runs over the fairly level surface of the Causse Mejan. One or two stops were made to examine some fine dolines with their covering of deep red soil.

The descent into Florac is slightly more precipitous than the ascent from Les Vignes and most of the party elected to scramble down the valley side arriving in the town a little before the coach, which had to negotiate, in stages, several sharp hairpin bends.

Sunday, 23 September

The distance from Florac to Clermont Ferrand (250 km. approximately) and the unfavourable weather—only the third wet day—militated against long or frequent stops *en route.*

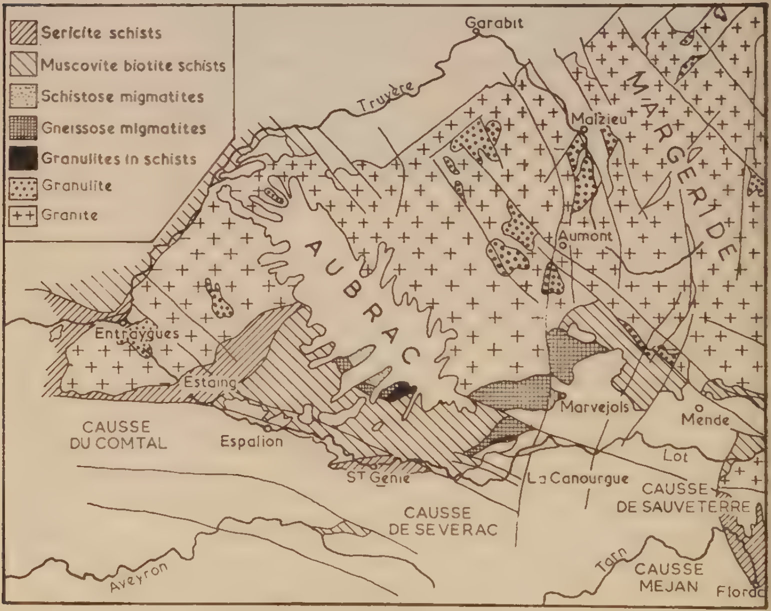


Fig. 14. Margeride Massif

The road from Florac (N. 107) runs via Mende and St. Amans to Rimeize, where a granulite facies of the main Margeride granite was examined. The main granite mass is crossed from just north of Mende to Loubaresse, a few kilometres south of the viaduct at Garabit. This viaduct, which carries the railway 400 ft. above the deep Truyère valley, was constructed in 1882 by Eiffel, who thereby gained experience useful in his construction of the Tower in 1889.

From St. Chely R.N. 9 was followed all the way to Clermont Ferrand via St. Flour, Massiac and Lempdes. Between the two latter towns the Allagnon River flows in a gorge cut into basement rocks including sillimanite gneisses. The Allier was closely followed as far as Issoire, and from there to Coudes the road runs through the deep gorges of that river. At Coudes the river was left behind and the Plain of the Limagne was crossed to Clermont Ferrand.

Dr. Lapadu-Hargues was the guest of honour at dinner in the Grand Hotel in the evening. Dr. S. O. Agrell expressed the thanks of the party to Dr. Lapadu-Hargues for his part in the direction and organisation of the excursion and also for his entertainment on one or two occasions. He asked that the thanks and best wishes of the members should be given to Mr. R. Michel, Mr. Peterlongo and M. Lavarenne, who had also contributed to this most enjoyable field meeting. Dr. Lapadu-Hargues replied on behalf of himself and his colleagues.

Dr. B. C. King proposed a vote of thanks to the Secretary, Mr. R. Bradshaw, for his part in the arrangements and general administration.

Most members spent the next day, Monday, 24 September, in Clermont Ferrand and caught the night train to Paris, where they had breakfast before boarding the train for Dieppe. London was reached via Newhaven at 5.45 p.m. on Tuesday, 25 September.

The Secretary acknowledges with grateful thanks the facilities provided for the preparation of some of the diagrams by Professor H. C. Darby in the Department of Geography, University College, London.

BIBLIOGRAPHY

CULLIS, C. G. & D. A. LOUIS. 1902. Report of the Long Excursion to the Auvergne. *Proc. Geol. Assoc.*, **17**, 269.

GLANGEAUD, P. 1923. La Chaîne des Puys. *Bull. Serv. Carte Géol. France*, No. 135.

JUNG, J. 1936. Itinéraire géologique à travers la Basse—Auvergne et la Montagne Bourbonnaise. Clermont Ferrand.

———. 1939. Itinéraire géologique à travers le Bas-Limousin et le Cantal. Clermont Ferrand.

———. 1946. Géologie de l'Auvergne et de ses confins bourbonnais et limousins. *Mem. Serv. Carte Géol. France.*

——— & M. ROQUES. 1938. Les schistes cristallins du Massif Central. *Bull. Serv. Carte Géol. France*, **39**, No. 180.

LAPADU-HARGUES, P. 1948. Les massifs de la Margeride et du Mont Lozère et leurs bordures. *Bull. Serv. Carte Géol. France*, **46**, No. 222.

MICHEL, R. 1948. Étude géologique du Plateau de Gergovie. *Mem. Soc. d'Hist. Nat. d'Auvergne*, No. 4.

ROQUES, M. 1941. Les schistes cristallins du Massif Central. *Mem. Serv. Carte Géol. France.*

———. 1949. Introduction à la geologie de l'Auvergne. Clermont Ferrand.

(A more detailed bibliography can be found in the above-mentioned works.)

General guides:

Guide Michelin—Auvergne. Gorges du Tarn.

Maps:

General: Carte Michelin 1: 200,000. Nos. 73, 75, 76, 80.

Geological: 1: 320,000. Clermont Ferrand and Rodez sheets.

1: 80,000. Gannat, Clermont, Brioude, Tulle, Mauiriac, Brive, Aurillac, Saint Flour, Figeac, Mende and Sevrac sheets.

Summer Field Meeting in East Yorkshire

22 July–5 August 1950

Report by the Directors: VERNON WILSON, C. W. WRIGHT,
J. E. HEMINGWAY, H. C. VERSEY, and W. S. BISAT

with

(A) 'Additional records of mollusca from the Dimlington area, and the relation of the beds to the Bridlington Crag'

by W. S. BISAT, and

(B) 'Note on the age of the Holderness shells'

by D. F. W. BADEN-POWELL

Received 17 March 1953

THE PREVIOUS OCCASION on which the Association held a long field meeting in East Yorkshire was in 1934, when a comprehensive study was made of the whole of the Jurassic sequence. On this recent visit the attempt was made to strike a balance between the claims of Jurassic and Cretaceous stratigraphy, general geomorphology and the Drift geology of the area. Malton was chosen as the headquarters for the Meeting and the members arrived there on the evening of the 22nd July.

Sunday, 23 July

Scarborough and Hackness Hills. The party assembled in the grounds of the Talbot Hotel where Dr. Wilson gave a brief account of the local geology and pointed out such features of the district as were visible. This was followed by an account of the geology to be seen during the ensuing four days. The members, numbering thirty, then proceeded by coach along the south side of the Vale of Pickering through Seamer to Scarborough.

In Scarborough, the party proceeded on foot to the Castle Hill, from which there was a clear view of the coast as far south as Flamborough Head, and the general layout of this part of the coast was explained. Beneath the Castle ramparts on the north side the excellent section in the lower Corallian beds was then examined in detail. These consist of the Hambleton Oolite sequence and the underlying Lower Calcareous Grit (Wilson, *Proc. Geol. Assoc.*, **60**, 240–4). Among the numerous fossils recorded special mention is made of a fine specimen of *Goliathiceras sp.*, obtained from the lower part of the Hambleton Oolite about 10 ft. from the top of the 'Ball Beds', which form the highest part of the Lower Calcareous Grit.

The party rejoined the coach and took the road through Scalby along the northern side of the pre-glacial Valley of the River Derwent and up the steep scarp slope of the Hackness Hills, where at Suffield, they examined the lower, brown, sandy limestones and overlying Sponge-Coral Rag forming the lower part of the Hambleton Oolite Series at a convenient quarry in Limestone Lane. Many fine calcareous sponges, terebratulids and other reef fossils were obtained. Continuing westward to the end of the lane, the old Suffield Limestone Quarry was reached. This old section in the beds of the upper part of the Hambleton Oolite Series is once again being actively worked and some 20 to 25 ft. of massive oolites, with shells preserved in calcite, were seen. The coach was rejoined near Hackness Hall and the journey continued to Forge Valley—the origin of this glacial overflow channel being explained *en route*. About half-way down the Valley some 30 ft. of impure brashy and gritty limestones of the middle Calcareous Grit were examined in the old White Quarry.

Next, the two quarries in the Osmington Oolites close to Betton Farm, three-quarters of a mile north-east of East Ayton, were visited. That on the north side of the road shows parts of the base of the massive coral reef resting, with a very irregular junction, on underlying oolites. Massive *Thamnasteria concinna* were seen to be well bored by *Lithophaga inclusa*, *Chlamys nattheimensis*, *Exogyra nana*, *Bourguetia striata*, and *Cidaris* spines were common. The large old quarry a few yards to the south, between the road and the farm buildings, shows about 12 ft. of soft calcareous mud full of broken fossils and reef detritus, with an occasional stack of massive reef rock. The party then visited the extensive workings on the hillside to the west of the village, in the outwash gravels deposited by the waters which cut the overflow channel of Forge Valley. Many rock-types were recognised among the erratics examined. The return route to headquarters was along the northern edge of the Vale as far as Pickering and then across the alluvial flats southward to Malton. V.W.

Monday, 24 July

Cayton Bay and Filey. The party travelled direct to Cayton Bay and then spent the whole day on foot, examining the coast sections down to Filey. At Osgodby Nab, at the northern end of Cayton Bay, the Millepore Beds were first seen. Here they consist mainly of calcareous sandstones with shell debris and *Entalophora straminea.* At the south end of Cayton Bay the Cornbrash crops out at the base of the cliffs but is usually obscured by beach sand. On this occasion, however, a few exposures about 2 ft. thick were visible and several crushed specimens of *Microthyris lagenalis*, together with *Serpulae*, were collected. A few yards farther on is the section of Red Cliff at the foot of which shales and sandstones of the Kellaways Rock are well displayed. These are succeeded by 19 ft. of Hackness Rock and overlain by about 120 ft. of Oxford Clay which forms the greater part of the cliff. The lower part of this sequence was examined but unfortunately no fossils were recorded. The lower Calcareous Grit, capping the Oxford Clay, was inaccessible at this point. The high Red Cliff is terminated to the east, and separated from Yons Nab beyond by the Red Cliff fault which throws the Oxford Clay and Lower Calcareous Grit down to the west.

As the tide was now almost at its highest, it was possible to examine only the succession of Grey Limestone beds and overlying Upper Estuarine sandstones and sandy shales in the Yons Nab cliff section. Around the Nab, to the east, lies Gristhorpe Bay with its unstable Boulder Clay cliffs, up which the party scrambled and continued the route along the cliff-edge to Filey Carr Naze. Here, in the lower part of the cliffs, the Corallian from the upper part of the Lower Calcareous Grit up to the basal beds of the Osmington Oolites is well developed, principally as shallow-water sandy limestones with large numbers of shallow-water fossils and much broken fossil debris. The succession (described in *Proc. Geol. Assoc.*, **60,** 242–7) was examined and good collections were made. This concluded the day's programme, but on the way back a halt was made between Staxton and Seamer, where Mr. J. Maclaren of Whitby conducted the party to a recently-excavated site in Starr Carr from which Maglemose remains had been excavated. After Mr. Maclaren had been thanked for his interesting account the homeward journey was resumed. V.W.

Tuesday, 25 July

The Eastern Howardian Hills. The party travelled by coach down the York Road to Peckondale Hill, near High Hutton, where about 46 ft. of Oxford Clay are visible in a large pit. These shaly clays with silty bands were examined and large numbers of compressed Kosmocerates were collected from five different levels. The ammonites appear to belong to the finely-ribbed *Kosmoceras* (*Gulielmiceras*) aff. *stutchburii* (Pratt) and its allies.

A few yards farther brought the members to the old sand-pit on the south side of the road, where about 30 ft. of soft white and light grey Kellaways Sands are exposed near the River Derwent. Formerly the sands were worked for refractory purposes. A further short walk across Crambe Beck, and Welburn cross-roads were reached. In the large quarry near-by about 10 ft. of Middle Estuarine Sandstones overlie some 30 ft. of thickly-bedded Whitwell Oolite which is being actively worked, and from which *Entalophora straminea* was recorded. The coach was rejoined and the route continued down into the overflow channel of Glacial Lake Pickering at Kirkham Abbey, and thence eastwards for seven miles over undulating faulted country, mainly of Corallian rocks, to North Grimston, where the classic sections in these rocks were studied. In the sides of the road leading up North Grimston Hill, to the east of the village, the upper soft sandstones of the Lower Calcareous Grit were seen near the foot, and in ascending the hill the successive beds of the Urchin Marls (Osmington Oolite Series) were examined, and specimens of *Hemicidaris intermedia*, *Nucleolites scutatus*, *Thecosmilia annularis*, *Lithophaga inclusa*, *Chlamys nattheimensis*, *Lopha gregarea* and casts of gastropods were collected. At the top of the hill the large quarry in the Coral Rag was visited and the origin of the masses of blue-grey chert provided much discussion.

A short distance farther east is a large quarry on the south side of the road in a small faulted area of the Upper Calcareous Grit, known locally as the North Grimston Cement stones, consisting of hard and soft beds of calcareous cementstone, from which members collected specimens of *Gryphaea dilatata* and fragments of ammonite casts. A few yards still farther east the Kimmeridge Clay was seen in an old pit by the roadside but unfortunately its junction with the overlying Red Chalk marl and the succeeding rubbly-white Chalk was obscured by talus. After a good day's collecting, the party returned to Malton. V.W.

Wednesday, 26 July

The western Howardian Hills and southern part of the Hambleton Hills. On this day the coach took the members westward along the northern flank of the Howardian Hills. The first stop was made at a sand-pit at the eastern end of Slingsby, where the following sequence occurred:

	ft.
4. Soft grey limestone-marl	up to 2½
3. Pebbly wash of Corallian limestone material with variable thickness of old soil above	4–5
2. Soft brown sand, current-bedded in places	8–10
1. Gravel, mainly sandstone, quartzite and blue limestone pebbles ...	4–5

In the above section the two top recent beds lie as irregular pockets and lenses on the underlying sand, and the material appears to have been washed down from the Corallian slopes to the south.

The eastern end of the Coxwold–Gilling Gap was crossed between Hovingham and Stonegrave, and the positions of the Gilling and Kilburn Faults were pointed out in relation to the topography.

About half a mile west of Stonegrave the fine section in the Nunnington railway-cutting was examined. Here some 30 ft. of massive sandstones of the Upper Calcareous Grit are resting on 8 ft. of the Osmington Oolite Coral Rag in which branching and compound corals and algal heads are common. The route was continued through Oswaldkirk and Ampleforth to Byland, where lunch was taken in the precincts of the old Cistercian Abbey. About two miles farther west the party ascended White Horse Hill up to the Corallian plateau, and while the members were mustered on the eye of the White Horse, the various features of the Pennines from south Durham southwards were pointed out, and also the features of the Jurassic topography to the south-east as far as the Chalk Wolds.

Near the White Horse is the Roulston Scar Cliff section in the Lower Calcareous Grit. These beds were examined as the steep descent was made. The route was continued by coach to Low Kilburn, where the members took a short walk to Snape Hill. The northern side of this low eminence is marked by the Kilburn–Ampleforth Fault, on the north side of which the Jet Shales (Upper Lias) were examined in an old pit, while to the south, in the large quarry, were seen the Upper Calcareous Grit cementstones which form the northern slopes of the hill.

After tea at Coxwold the route traversed undulating wooded country through Yearsley to Grimston Moor, where, in a quarry about a mile west of Coulton, the Whitwell Series was examined. The sequence, which is much more arenaceous than in the type-area near Whitwell, is as follows:

	ft.	ins.
6. Thick, brown, current-bedded flaggy sandstone, weathering to a soft red-brown sand	5	0
5. Thin, soft 1 in. to 2 in. sandstone beds	1	9
4. Soft marly sand, with a grey clayey seam at the base and another about 2 ft. above the base	3	6
3. Grey-purple silty shales	6	0
2. Massive blue-centred sandy limestone; the top foot is a detrital shelly oolite	6–7	0
1. Sandstones with occasional plant fragments.		

The party then returned to Malton. Later in the evening the members assembled for discussion and review of the first four days of the meeting. Mr. B. Ainsley thanked Dr. Wilson, on behalf of the members present, for his most interesting excursions. V.W.

Thursday, 27 July

Sewerby to Danes Dyke: Upper Chalk. Despite much seaweed on the scars at Sewerby, and rather dirty cliffs due to downwashed Boulder Clay, there was some good collecting in the *Inoceramus lingua* Zone of the Upper Chalk. This is the classical English section of the northern facies of this part of the Senonian.

Several ammonoids, two *Scaphites binodosus* and a good fragment of *Glyptoxoceras* were found, although they are very rare in this, the lower, division of the *Lingula* Zone. The characteristic lithistid sponges were abundantly represented and members obtained good specimens of most of the common species, as well as some rarer ones. The most interesting find in this group was a well-preserved fragment of a very large species of *Coeloptychium*.

The next two zones below, of *Marsupites testudinarius* and *Uintacrinus westfalicus*, each yielded reasonably good and abundant specimens of their characteristic crinoids. C.W.W.

Friday, 28 July

Flamborough Head: Middle and Upper Chalk. The party first visited North Sea Landing, a small bay cut in chalk of the *Terebratulina lata* Zone, so very hard that the wave-worn scars are at first sight quite unrecognisable as chalk. From the point between North Landing and the Thornwicks the magnificent cliffs of the north side of Flamborough Head were examined at a distance.

The next call was at Selwicks Bay, out in the Zone of *Hagenowia rostrata*, the local equivalent of the *M. coranguinum* Zone. The chalk here is in the lower part of the zone and is exceedingly hard. The junction between the flinty and flintless chalk occurs about a third of the way from the base of the zone and about this junction half a dozen fragments of *Actinocamax westfalicus* were seen, together with a single *Micraster coranguinum*—a rarity in Yorkshire.

The cliff-path was then taken to High Stacks and the party descended to the beach again on the south side of the Head. In a rather arduous walk along the fine section of the upper *H. rostrata* Zone to South Landing, many small fossils were found in the air-weathered patches on the cliffs. The local zone-fossil was very abundant. A single *Salenia granulosa* turned up and a badly-preserved *Parapuzosia* sp. was noted near High Stacks. C.W.W.

Saturday, 29 July

Speeton: Speeton Clay, Red Chalk and Lower Chalk. As the party approached the Speeton section it was fortunate in seeing some of the lower part of the Valanginian D. beds, including the pale grey stony bands of D.6, in a small beach exposure. Apart from the numerous belemnites (*Acroteuthis* spp.), the characteristic little *Pseudolimea*, a species with 'taxodont' hinge, described by Woods as *Limea* cf. *granulatissima* (Wollemann), was found.

The Upper part of the D. (lower Hauterivian) yielded many *Acroteuthis* and several *Lyticoceras* and *Distoloceras* species. The zonal belemnite *Hibolites jaculoides* Swinnerton (*jaculum* auctt.), *Lyticoceras regale*, *Speetoniceras*, *Simbirskites* spp., and *Spitidiscus rotula* were among the typical fossils picked up on the sloping section of C. beds (Lower to Upper Hauterivian).

Oxyteuthis spp. and large specimens of *Hoplocrioceras* were seen in the Cement Beds of Middle B. (Barremian). The dark shales of Upper B. (Upper Barremian or Lower Aptian according to the system used) provided *Grammatodon securis* and fragments of *Parancyloceras bidentatum*.

Only very poor exposures of the A. beds (Aptian to Upper Albian) were seen, but from the upper part, the equivalent of the 'Minimus-thon' of North-west Germany, abundant *Neohibolites* were collected.

As a result of a large landslip, a few years ago, the junction between the Speeton Clay and the Red Chalk is now seldom seen, and on this occasion the beach level in Red Hole was very high. Many small belemnites, lamellibranchs and brachiopods were found in the Red Chalk, though not the much-discussed pterodactyl bones. Several specimens were obtained of the large *Concinnithyris* from the grey-green bed in the middle of the Red Chalk.

Besides the abundant *Inoceramus* and *Aucellina*, the base of the Lower Chalk yielded a few echinoids, including *Hemiaster morrisi*, *Holaster subglobosus* and *Trochotiara ornata*.

On the way back to the coach the remarkable Danish and Saxon Parish Church of Speeton was briefly inspected. C.W.W.

Sunday, 30 July

Yorkshire Wolds and Humber Gap: Chalk and Drift. The first stop of the day was at the quarry at Kiplingcotes Station, in comparatively soft chalk of the *Holaster planus* Zone. Here, fortunately, was exposed a lenticle of 'chalk rock'—a fossiliferous patch of nodular, rather ferruginous, chalk, probably preserved from solution by the presence of a large ammonite, which yielded a few fragmentary gastropods among the crowded asteroid ossicles and pieces of echinoids.

A quarry by the railway to the south-west, and also in the *H. planus* Zone, provided several good specimens of *Infulaster excentricus*.

At Little Weighton Station a quarry in the lower *Hagenowia rostrata* Zone was briefly inspected. A few large specimens of the nautiliform *Inoceramus involutus* were to be seen in the large tabular flints.

After lunch at North Ferriby, the site of the recently-discovered Iron Age boats, on the Humber shore, was examined. The succession of Boulder Clay, its top pierced by rootlets of *Betula nana*, followed by dark peat and then grey and reddish warps, was clearly seen.

Farther west, at Redcliff, the terminal moraine was inspected and numerous lumps of chalk of the *Belemnitella mucronata* Zone were found in the Boulder Clay.

Mrs. H. V. Wright kindly provided tea on the lawn at Tower House and afterwards the abilities of sceptics to dowse was demonstrated, to their disgust, in the garden.

Mr. Joysey voiced the thanks of the party to Mr. C. W. Wright who had so ably directed the four days of the excursion; to Mr. E. V. Wright who had assisted on the last two days and to Mrs. H. V. Wright who had very kindly entertained the party to tea. C.W.W.

Monday, 31 July

The Yorkshire Wolds. The excursion began at Cowcliff Quarry, near Wharram, where the Middle Chalk (*Terebratulina* Zone) was seen faulted against Kimmeridge Clay, with a thin covering of Carstone and Lower Chalk. The fault was pointed out as showing a repetition of movement along a Kimmerian line. From a view-point near Towthorpe Wold the peneplaned surface of the Wolds, and its continuation on the Cleveland Moors, was noticed. Several dry valleys in this peneplane were seen and Fairy Dale, with its roughly rectangular bends and two periods of erosion, was taken as typical. The flint gravel of the Fairystones is regarded as a product of the first period of erosion and fragments of sandstone and red chalk therein as pointing to the previous existence of Older Drift on the nearby Wold summits. In Burdale quarries, Lower Chalk, *plenus* Marls and Middle Chalk were examined, the whole series showing disturbances associated with valley creep. After lunch in the much-dissected Thixendale area, the party went by coach along Water Dale, noting an inlier of Kimmeridge Clay, and along the edge of the escarpment from Aldro to Wilton Beacon. The position of Lower Cretaceous rocks in Painsthorpe Dale was pointed out. The Wolds were then crossed to Sledmere where traces of a residual clay were seen in old quarries. Such a clay is very rarely seen in this area. At Weaverthorpe, the mature topography of the Great Wold Valley was contrasted with the youthful form of the Thixendale valleys and a greater antiquity deduced for it. A quarry east of the village shows highly disturbed Chalk that lies on a narrow belt stretching across the Wolds to Bempton, and probably represents a re-activation in immediate post-Cretaceous times of the Kimmerian Gilling Fault. After tea at Sherburn, the party returned to Malton. H.C.V.

Tuesday, 1 August

The Market Weighton Axis. The party went by coach across the Jurassic foothills west of the Chalk escarpment to Pocklington and Market Weighton, stopping for a brief examination of the Keuper Marls near Garrowby and late-Glacial outwash-gravels near Hayton. At the well-known Rifle-butts section near Goodmanham an attenuated representative of the Red Chalk containing ironstone pebbles was seen, resting on *angulatum* beds of the Lower Lias of the Market Weighton Anticline. Fossiliferous beds of Lower Chalk, with pink bands, were seen in an adjacent section. These exposures are near the outlet of a direct overflow channel from lakes dammed by ice on the eastern slopes of the Wolds, and reference was made to an extensive gravel delta which occurs where the valley enters the Vale of York. The route continued along the foot of the Wolds and it was seen how successively higher members of the Jurassic system emerge from under the Cretaceous unconformity. The Cave Oolite (Millepore Limestone) was examined near South Newbald, and the highly fossiliferous Kellaways Rock at South Cave Station. A section on the hillside above the station showed Red Chalk on Upper Jurassic clay, thus completing the demonstration of the Market Weighton Anticline. The party then went to the Lias escarpment near Hotham, where clays and argillaceous limestones belonging to the *planorbis* and *johnstoni* beds of the Lower Lias (horizons lower than any exposed on the Yorkshire Coast) were examined. After tea in Market Weighton, Dr. W. D. Gill moved that the thanks of the members be accorded to Dr. Versey for his most comprehensive and interesting excursions. The party then returned by coach to Malton.

H.C.V.

Wednesday, 2 August

Newtondale, Goathland and Whitby. The party first traversed the flat floor of glacial Lake Pickering from south to north, *en route* for Blackamoor and the Middle and Lower Jurassic rocks exposed there. The lake-sediments are here approximately 100 ft. thick, indicating that in pre-Glacial times a marine embayment more than 25 ft. deep stretched from Filey westwards as far as Kirkby Moorside.

North-east of Pickering the dip-slopes of the Corallian were ascended. From a view-point near Kingthorpe the party looked into Newton Dale, the direct overflow channel which cuts through the Upper Jurassic succession, and which carried the ice-dammed waters of the Eskdale system of glacier-lakes as they drained south to Lake Pickering. From the similarity in development shown by Newton Dale and Thornton Dale (cut by Dalby Beck) to the east, as well as other features, it was concluded that Newton Dale was mainly cut before Newer Drift times and that it had only been deepened by glacial overflow-waters. From Saltersgate other views of Newton Dale, where it breaks through the Corallian escarpment, were obtained. The impressive Hole of Horcum, developed by centripetal spring-head sapping through the cover of Lower Calcareous Grit, was briefly examined.

The party then continued to Goathland, noting the intake of Newton Dale, near Fen Bogs, as well as Moss Dyke and its associated parallel, marginal overflow channels, which mark the position of maximum glacial advance on this spur in Newer Drift times. The position of pre-Glacial valleys in the boulder-clay-covered region around Goathland was pointed out and the form and youthful character of a post-Glacial gorge with its several waterfalls was seen at Eller Beck. Here the type-section of the marine Eller Beck Bed was examined, interbedded in the sandstones and shales of the Middle Jurassic Deltaic Series. A considerable lamellibranch and gastropod fauna, preserved in dickite (and, more rarely, in a pale sphalerite), was collected from this horizon.

Farther downstream at Beckhole, the Dogger, with its characteristic basal layer of phosphatised pebbles, was examined and its relation to a sandstone-filled washout in the overlying Lower Jurassic Deltaic Series was noted. Representative ammonites from the underlying Alum Shales of the Upper Lias were also collected. The rapid lateral variation in the Dogger was demonstrated here since, in the adjacent Wheeldale Gill, a banded ironstone, with alternations of siderite-mudstone with chamosite-oolite, had been mined from this horizon. After an examination of the tips from these mines, heavy and persistent rain curtailed the remainder of the day's programme. As an alternative, members continued by coach to Whitby, where they examined the unique collection of Liassic type-ammonites, at the museum of the Whitby Literary and Philosophical Society.

J.E.H.

Thursday, 3 August

Holderness Drifts. The party, numbering about fifteen, travelled by coach via Driffield to Holderness and called first at the gravel pits at Catwick, west of Hornsea. These pits form part of a long narrow chain of workings in glacial gravels extending from North Frodingham southwards to Catwick, and thence eastwards towards Hornsea, where they reach the coast-line. The Catwick pits reveal two beds of gravel, separated by about 15 ft. of laminated clays, the lower gravel being largely below water-level. This long narrow tract of gravels apparently marks a line of glacial drainage probably extending from the Wolds in the Ruston Parva area, and passing out to sea via the Hornsea gap. The presence of a small remnant of a plug of Purple Clay at the south end of the Hornsea promenade suggests that ice of that period was responsible for blocking this outlet to the sea and consequently for diverting the drainage of most of the eastern Wolds southwards, via the basin of the River Hull, to the Humber. In the same way the great plug of Purple Clay centred on Withernsea completely blocked the original Humber outlet at that point and diverted the estuary to its present south-easterly course.

The post-Glacial peat on the coast at the small depression at Skipsea landing was next visited, with its numerous birch trunks, and underlying freshwater clay. A collection of the freshwater mollusca, made by Mr. and Mrs. Ainsley, was examined by Mr. A. G. Davis, who determined species

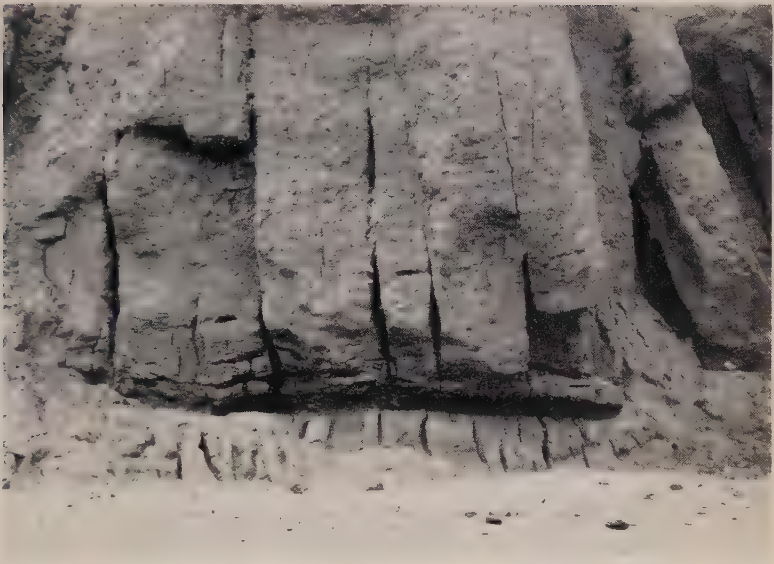


Photo C. W. Mason

A. Upper Drab Clay with vertical jointing resting on Middle Drab Clay at Great Cowden, 6000 yards south of Hornsea sea wall

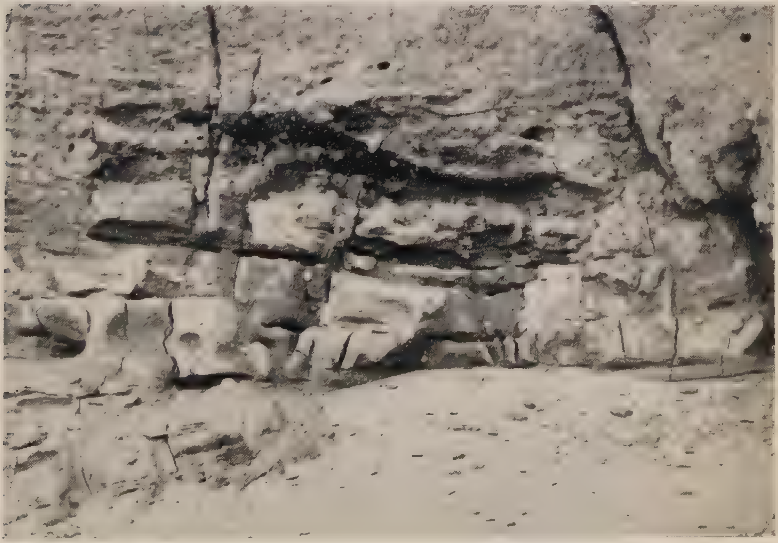


Photo C. W. Mason

B. Base of Lower Drab Clay, well bedded and with pale and dark banding, resting on Sub-Dry Clay at Moor Hill, Skirlington, three-quarters of a mile north of Atwick road end, north of Hornsea

as follows: *Bithynia tentaculata* (Linné), *Lymnaea peregra* (Müller), *Myxas glutinosa* (Müller), *Valvata cristata* Müller, *V. piscinalis* (Müller), *Planorbis crista* (Linné), *P. contortus* (Linné), *Anodonta cygnea* (Linné), *Pisidium nitidum* Jenyns, and *Sphaerium corneum* (Linné).

It was pointed out that the shallow depression in which the freshwater clays and peat accumulated had originated as a deeper hollow in Glacial times, and that this was partially filled by Upper Drab Clay.

After lunch at Skipsea the party examined the boulder clay cliffs north of Atwick. These show the lower part of the Middle Drab, the Lower Drab and Sub Drab Clays. The last-mentioned clay, which has relatively few erratics and is especially free from chalk, was seen in an arched-up mass about three-quarters of a mile north of the end of Atwick road. The base of the Lower Drab Clay is well-bedded, with pale and dark banding (see Plate 10). The Lower Drab Clay carries numerous igneous and other erratics and has a sporadic 'head' of friable clay at its summit. This 'head' contains very little chalk except at the top, where large masses and streaks of soft chalk occur here and there, sometimes containing the high chalk fossil, *Belemnitella mucronata*, which is unknown in the Yorkshire chalk. The lower part of the Middle Drab Clay contains more chalk erratics, together with black flints, and is of a slightly warmer and darker colour than the underlying Lower Drab Clay.

The party then journeyed to Great Cowden where the magnificent exposures of the red band at the top of the Middle Drab Clay are seen. Hereabouts the Upper Drab Clay forms fine vertical scars, with vertical jointing, resting on top of the Middle Drab Clay near beach level (see Plate 10). This red band, whilst very variable in thickness, and often absent, occurs in occasional patches throughout the whole length of the cliff exposures from Aldbrough to at least as far north as Atwick, rising gradually but irregularly northwards, though temporarily sinking below sea-level at the Hornsea gap.

After tea at Aldbrough the party returned by coach to headquarters.

W.S.B.

Friday, August 4

Holderness Drifts. The party travelled by cars to Keyingham where some time was spent collecting from the very fossiliferous gravels which are of the same age as the near-by Kelsey Hill deposits. The following list of species collected on this occasion has been drawn up by Mr. Baden-Powell: *Corbicula consobrina* (Caillaud) (abundant), *Ostrea edulis* Linné (abundant), *Mytilus edulis* Linné, *Astarte borealis* (Chemnitz) (one valve), *Cyprina* sp., *Cardium edule* Linné (common), *Spisula elliptica* (Brown) (four valves), *S. truncata* (Mont.) (one valve), *Tellina balthica* Linné (common), *Corbula gibba* (Olivi), ?*Pholas* sp., *Dentalium entalis* Linné, *Littorina littorea* (Linné) (one shell), *Natica alderi* (Forbes) (one shell), *Buccinum undatum* Linné, *B. undatum* cf. var. *caeroleum* Sars, *Nassa reticulata* (Linné), *N. pygmaea* (Lam.), *Bela* cf. *scalaris* (Möller), *Purpura lapillus* (Linné). Of these *Bela* and *Astarte* indicate cold conditions, whereas *Nassa* points to a warmer climate.

The general opinion of the party was that these were littoral gravels, and the fauna indicated that the beds were of equivalent age to the March gravels, as was suggested years ago by Lamplugh and others. Mammalian bones are frequently found in this pit, as in the old Kelsey Hill and Burstwick pits, but none was found on this occasion. Numerous black flints of large size, unknown in the Yorkshire chalk, were seen, and many igneous erractics (including laurvikite and various granites), evidently derived from the earlier Drab Series.

The party then proceeded to Holmpton and after lunch examined the cliff and foreshore exposures. Owing to active sea erosion, the sections were very clear, and the Lower Purple Clays, the Drab Series of clays and the Basement Clay were seen in the cliff, while on the foreshore patches of the blue, shelly Sub-Basement Clay, with *Dentalium*, were seen protruding through the greener Basement Clay. From this blue clay numerous marine shells were extracted, and the following list of those found on this visit, together with numerous other species collected by the Director from similar exposures at Dimlington, farther south, has been drawn up by Mr. Baden-Powell: *Chlamys islandica* (Müller), C., *Leda pernula* (Müller), C., *Astarte borealis* (Chem.), C., *A. sulcata* (da Costa), *A. sulcata* (close-ribbed form), C., *A. montagui* (Dillwyn), *A. elliptica* (Brown), C., *Cyprina islandica* (Linné), *Cardium groenlandicum* (Brug.), C., *C. echinatum* Linné, *Tellina balthica* Linné, *T. calcarea* Gmel., C., *Mya truncata* Linné, *M. truncata* var. *uddevallensis* Hancock, C., *Saxicava pholadis* (Linné), *Dentalium striolatum* (Stimp.), *Turritella communis* Risso, *T.* cf. *tricarinata* (Brocchi), E., *Natica clausa* Brod. and Sow., C., *Amauropsis islandica* (Gmel.), C., *Purpura incrassata* (Sow.), E., *P. elongata* (Wood), *P. lapillus* (Linné), *Buccinum undatum* Linné, *Neptunea despecta* (Linné), C., *N. despecta* var. *subantiquata* (Maton and Rackett), *Bela nobilis* (Möller), C., *B.* cf. *borealis* (Reeve), C., *Balanus porcatus* da Costa, *B. hameri* (Asc.), Bryozoa. C.=cold-indicator: E.=extinct form.

The topmost layers of the Basement Clay, as seen in the cliff, were rather silty and unusually rich in the remains of *Tellina balthica*. The suggestion is that this point, at which the Basement Clay dips rapidly northwards below the beach, marks the south bank of the Glacial Humber, and that during a temporary amelioration of the climate the shell-fragments were drifted in from adjacent sand-banks and incorporated in the topmost layers of the Basement Clay, while farther south, at Dimlington and

Easington, the moss *Hypnum aduncum* was obtaining a precarious foothold in shallow pools on the surface of the clay.

The party then journeyed to Easington for tea, and before members dispersed Mr. D. F. W. Baden-Powell moved a vote of thanks to Mr. Bisat for his direction of the excursions in Holderness. Mr. B. Ainsley also proposed a vote of thanks to Mr. D. R. Hughes, who had acted as Honorary Secretary for the Field Meeting. W.S.B.

APPENDIX A

Additional records of mollusca from the Dimlington area, and the relation of the beds to the Bridlington Crag

by W. S. BISAT

A FEW YEARS ago the late A. S. Kennard revised the determinations of the shells from Dimlington in the Geological Survey collection. This collection, made many years ago, includes not only the greater part of the species in the above list, but, in addition, such littoral forms as *Cardium edule*, *Zirfaea* (*Pholas*) *crispata*, and *Littorina littorea*, of which none had been found by the writer up to 1951.

There is also a record by H. B. Woodward (The Geology of England and Wales, 2nd Edn., 1887, 498) of perfect specimens of *Nucula cobboldiae* having been found by Sir Charles Lyell and Professor Hughes in a shelly layer of the Basement Clay at Dimlington.

These littoral species, missing from later collections, have long presented a puzzle, and I have concluded, in this connection, that they must have come from some bed not seen in recent years. *Zirfaea crispata*, which has been recorded by Lamplugh from both Bridlington and Dimlington as occurring whole, in cemented sand (representing the cast of its boring), has always presented a particularly tantalising problem.

In the autumn of 1951 close search of the top of the Basement Clay between Holmpton and Old Hive yielded small fragments of *Cardium edule*, one small piece of the extinct *Nucula cobboldiae*, and a complete specimen of *Mya* enclosed in the cylindrical, cemented sand-cast of its boring. I have little doubt that this must be the horizon at which the *Pholas* occurred at Dimlington and Bridlington, and suspect that the *Mya*, which occurred with its cemented boring-cast in an upright position, at the top of the Basement Clay, may have been in its position of growth.

Viewed in relation to the above recent records, the remarks of Bedwell (*Geol. Mag.*, 1878, 518) take on an added significance. That writer, in describing a chance exposure of the Bridlington Crag on the foreshore at Bridlington wrote:

> I saw the horizontal section of the beds for myself, and observed that the complete bivalved shells, which were numerous, lay horizontally and showed no signs whatever of disturbance, and I concluded then and still think that they died and lived very near to where I found them. The beautiful *Nucula cobboldiae* in particular occurred with both valves perfect, while delicate as it is, it had never been assailed by any force so applied as to injure its exquisitely ornamented shell. The *Pholas crispata* which was exceedingly plentiful, was found invariably as a double shell, and indeed I have never yet seen a specimen of a single separated valve of that shell.

Also I have an original manuscript note of Rev. J. L. Rome, apparently written about 1866, in which he gives the following section of the Bridlington Crag:

1st. (going downwards)
An olive green sand at the bottom of it full of fossils—5 feet, sometimes more.
2nd. Brown clay average thickness from 2 to 3 feet, the whole of it full of shells.
3rd. The Purple [now Basement] Clay, not fossiliferous except in the upper 2 or 3 inches of it the Pholas being the most numerous.

It may be possible that both Bedwell and Rome were deceived by modern *Pholas*-borings in the foreshore clays, but such criticism can hardly be levelled at the sandstone-casts of *Pholas*-borings, or the perfectly preserved extinct *Nucula cobboldiae*, and I conclude that there is reasonable evidence for the correlation of the top of the Basement Clay at Bridlington and Dimlington and for at least some part of the molluscan fauna of the overlying Bridlington Crag being contemporaneous with that deposit, if not *in situ*. Thus, the lower part of the drift succession on the Holderness Coast appears to be:

5. *Drab Boulder Clay*, with abundant chalk and black flint erratics, and a well-mixed assemblage of igneous and other erratics from many sources, including Scandinavia and Scotland:

4. Occasional small silt-basins with laminae of Moss (Dimlington) and sporadic 'Crag' (with marine mollusca) at Bridlington (also a slight suggestion of the same at Holmpton):

3. *Basement Clay*, greenish in its upper part with small erratics of chalk, magnesian limestone and other rocks, often waterworn. Occasional derived valves of *Tellina balthica* and fragments of *Cyprina islandica*; darker in its lower part—almost black when moist—with strings of oxidised pebbles and occasional abundance of *Tellina balthica* (the latter probably not far from their parent bed). Occasional oxidised pebbles and sand, at the base:

2. *Sub-Basement Clay*, blue in colour, with sporadic but fairly large erratics, almost wholly of Scandinavian origin. Abundant molluscan fauna (derived),

including *Dentalium*, and small lamellibranchs (*Astarte*), sometimes in a state of perfect preservation:

1. *Undertill*, hard, dark drab clay with few erratics and no shells or chalk, but occasional cobbles of sandstone (probably Carboniferous). Seen only at one point a quarter of a mile south of Old Hive.

APPENDIX B

Note on the age of the Holderness shells

by D. F. W. BADEN-POWELL

THE PLEISTOCENE marine shells which have been found fall into two groups: those derived from sand and gravel at Keyingham; and those obtained from beds of till on the coast at Holmpton. These two assemblages are quite separate and distinct, and probably differ considerably in age.

The Keyingham shells include *Corbicula*, and appear to be from a marine bed, in place, which belongs to the Kelsey Hill Beds. No extinct species have been identified from the material collected at Keyingham, and records of former research show that extinct species are very rare indeed in this deposit; in this respect and in other ways it is probably the Yorkshire equivalent of the March Gravel of the Fen District.

The shells from the tills at Holmpton, the majority of which have been collected by Mr. W. S. Bisat but several of which were found during the present Field Meeting, are derived from marine deposits not seen *in situ* at this place, and differ from the Kelsey Hill Beds-assemblage in containing more frequent examples of extinct species. In the former respect they resemble the Corton Beds of East Anglia, and the original marine formation from which the Holmpton shells are derived may be of approximately the same age as the Corton Beds. It is considered unlikely that any of the Holmpton shells have come from a bed as old as the East Anglian Crag, because of the abundance of *Tellina balthica* and absence of *Tellina obliqua* among these derived shells. Also *Chlamys islandica*, which is unknown in the Crag, occurs at Holmpton.

The relation of these two marine horizons to the various beds of till remains to be worked out in detail, but as far as is known at present the Keyingham shell-bed appears to be later than some part of the Drab Series and may be overlain by a part of the Purple Series; the Holmpton and Dimlington shells are erratics in the Sub-Basement Bed, but a few also appear in higher beds.

It is hoped that these marine horizons will help to correlate the glacial deposits of different areas.

Field Meeting in South Wales

23–27 March 1951

Report by BRIAN SIMPSON

Directors: (A) Swansea District: D. Leitch, T. Neville George, Brian Simpson, W. B. Evans, T. R. Owen. Secretary: Brian Simpson.

(B) Cardiff District: J. G. C. Anderson, R. C. K. Blundell, Miss E. Richards. Secretary: Miss E. Richards.

Received 13 August 1953

(A) SWANSEA DISTRICT

23 March 1951

(Directors: Prof. D. Leitch, Brian Simpson, T. R. Owen)

The Ordovician-Carboniferous Succession on the North Crop of the South Wales Coalfield. The party left Swansea at 9 a.m. and proceeded via Morriston to Clydach, where a good view of the Glais recessional moraine was obtained (Halt 1, Fig. 1.) This ridge of glacial debris, about a mile in length, is one of the finest examples of a moraine in South Wales. It reaches a height of 193 ft. O.D. and rises to 150 ft. above the level of the alluvium at its western end. Its steep southern front overlooks a broad plain of outwash-gravels. Reference was made to the buried channel which had been shown by Prof. O. T. Jones to exist in this area. The floor of this ancient (probably pre-Glacial) valley is 146 ft. below sea-level.

The next halt was at Rhydyfro (Halt 2) in the Upper Clydach Valley. The River Clydach once flowed in a SSE. direction, across the line of the present Tawe Valley, towards the Neath area, but subsequently its upper portion was captured by the River Tawe, leaving a well-marked wind-gap (the Rhos-Alltwen Gap, 303 ft. O.D.) east of Pontardawe. The capture probably occurred in late Pliocene times, and the uplifts of that period are believed to have been responsible for the marked rejuvenation of the Upper Clydach.

The party next visited Gwaun-cae-gurwen (Halt 3), where an abandoned coal-tip yielded numerous examples of non-marine lamellibranchs from the *Modiolaris* Zone of the Lower Coal Series. The fauna collected included: *Anthraconaia* aff. *modiolaris* (J. de C. Sowerby), *Anthraconaia* aff. *williamsoni* (Brown), *Anthracosphaerium affine* (Davies & Trueman), *Anthracosphaerium exiguum* (Davies & Trueman), *Naiadites* spp.

North of Brynamman, the coach began to climb the long dip-slope of the

Millstone Grit, the top of which slope reaches 2000 feet O.D. in parts of the Black Mountains. The weather had, by this time, deteriorated, thereby preventing good views of the hollow and scarp formed by the Lower Coal Series and Pennant Sandstone respectively. A good section of the lower part of the Farewell Rock was examined (Halt 4). These wedge-bedded, rusty-weathering grits, yielding occasional plant fragments, were seen to pass down into grey, and then dark grey shales belonging to the *Gastrioceras subcrenatum* marine band. Good specimens of this goniatite, together with *Anthracoceras* sp. and *Dunbarella* sp., were obtained. These marine beds, which mark the true base of the Coal Measures, were seen to be faulted against the upper part of the Middle Shale Group.

Farther north, the lowest division of the Millstone Grit—the Basal Grit Group—was examined (Halt 5). These beds include white quartzites and quartz-conglomerates, which give rise to characteristic rocky (and obviously glaciated) surfaces. It was pointed out that the peculiar dips in the quartzite quarry were due to the effects of important dip-faults in this area. The most important fracture—the Cwmllynfell Fault—was shown to throw Carboniferous Limestone against the Basal Grits (Halt 6). The surface of the former was pitted with large swallow-holes.

In extremely wet weather, a large number of the party volunteered to leave the coach and climb up the upper portion of the Black Mountain escarpment (above Halt 7), seeing, *en route*, further effects of the Cwmllynfell Fault which here throws the Lower Limestone Shales and Plateau Beds against S_2 limestone, and examining the light-coloured D_1 oolite (with the peculiar Honeycomb Sandstone near its base) and the darker D_2 limestones, containing such characteristic brachiopods as *Productus productus* (Martin) and *Chonetes laguessiana* de Kon.

Descending the northern slopes of the Black Mountains, the party examined the Plateau Beds and the Brownstones. The former, a group of coarse conglomerates, are seen on both sides of the main road at Halt 7, where the rocks show the characteristic red jasper while the latter are exposed at a number of points along the road, and were examined in an excellent roadside exposure at Halt 8, where their brown colour, micaceous character and marked jointing were noted. Passing along the Sawdde Valley, the steeply-dipping Red Marls were seen. These extend to Pont-ar-llechau, where a halt was made to examine the position of the Siluro–Devonian boundary and the shallow-water deposits of Middle Ludlow age. Standing on the bridge which spans the Sawdde, the party observed the passage of the Tilestones upwards into the Red Marls, the stronger ribs of sandstone contrasting with the hollows formed in the marls along the course of the river. The Tilestones, exposed in a small roadside quarry behind the Three Horse Shoes Inn (Halt 9), were next examined. This series of greenish-grey, micaceous sandstones yielded only a few fossils, chiefly derived from the rotten bands. Among the fossils obtained were: *Chonetes striatella* (Dalm.), *Orthoceras* sp., and *Tentaculites* sp.

The party then examined the large quarries on the right bank of the River Sawdde, north of Pont-ar-llechau. Here excellent examples of ripple-marking were seen on the steeply-dipping quarry face. The beds exposed are the Grammysia-Trichrug Beds of Middle Ludlow age. Lithologically, the Trichrug Beds are, for the most part, arenaceous, consisting mainly of reddish-brown sandstones with some green shales, and bounded at the top and bottom of the sequence by quartzites. The Grammysia Beds, seen at the northern end of the quarry, are more varied in their lithology, consisting of grits, purple sandstones with layers of pebbles, and some shales. The following fossils were obtained: *Chonetes striatella* (Dalm.), *Wilsonia wilsoni* (J. Sow.), *Atrypa reticularis* (Linn.), Trilobite fragments, and Crinoid ossicles.

Still farther north, along the valley, a large quarry known as Colonel Jones' Quarry (Halt 10) was visited. Here the Ffairfach Grit and a group of rhyolitic ashes and tuffs were examined.

At Halt 11, in a small quarry about one mile from Llangadock, on the road to Bethlehem, the Llandeilo Flags yielded good specimens of *Ogygiocaris* [*Ogygia*] *buchi* and *Cryptolithus* [*Trinucleus*] faunas, in addition to a number of specimens of *Lingula*.

The party then proceeded to the road-cutting on the Llandeilo–Llanelly road (Halt 12), to examine a continuous section across the Siluro–Devonian boundary. It was pointed out that the lower part of the Red Marls here exposed could be correlated with the section above the bridge at Pont-ar-Llechau. The frequently-occurring bands of purple and green sandstone, many of them calcareous, were noted. Mr. Brian Simpson indicated that, in recent work, he had observed many small-scale structures indicative of shallow-water disturbance, some of which were seen on the rock-face. It was shown that here a considerable thickness of grey-green shales intervened between the Red Marls and the underlying Tilestones. Mr. Simpson recalled that Dr. Straw had shown how the dip of the Tilestones increased south-west from the Wye Valley and were overturned as this section was approached. He demonstrated this overturning by means of the excellent graded bedding here displayed. The Trichrug Beds were seen to overlie the Tilestones, the former showing their typical lithological development, except that, towards the base, a series of thin-bedded, somewhat-flaggy and calcareous sandstones occurred, in the decalcified bands of which an abundant fauna was present. Although this fauna was essentially shelly, it was indicated that specimens of *Monograptus leintwardinensis* had been obtained.

Some beds were composed almost entirely of *Atrypa reticularis* (Linn.).

Trilobites were also obtained (*Encrinurus* sp. and *Dalmanites* sp.). Mr. Simpson mentioned that this exceptionally rich fauna was being studied at the moment.

Below these fossiliferous beds the grey-green shales occurred, and beyond these, the distinct ridge formed by the Lletty Grit was pointed out.

The party then returned to Swansea, via Cross Hands and Pontardulais, tracing the succession, in ascending sequence, across the north crop of the coalfield. Attention was drawn to the contrast between the vegetation on the Red Marl, the Carboniferous Limestone and the Millstone Grit, respectively.

REFERENCES

Jones, O. T. 1942. The Buried Channel of the Tawe Valley near Ynystawe, Glamorgan. *Quart. Journ. Geol. Soc. Lond.*, **98,** 61.

Jones, R. O. 1939. The Evolution of the Neath-Tawe Drainage. *Proc. Geol. Assoc.*, **50,** 530.

Pringle, J. & T. N. George. 1948. South Wales. *Brit. Reg. Geol.* 2nd Ed.

Robertson, T. & T. N. George. The Carboniferous Limestone of the North Crop of the South Wales Coalfields. *Proc. Geol. Assoc.*, **40,** 18.

Straw, S. H. 1929. The Siluro–Devonian Boundary in South Central Wales. *Journ. Manchester Geol. Assoc.*, **1,** 79–102.

Ware, W. D. 1939. The Millstone Grit of Carmarthenshire. *Proc. Geol. Assoc.*, **50,** 168.

Williams, A., 1952. The Geology of the Llandeilo District, Carmarthenshire. *Quart. Journ. Geol. Soc. Lond.*, **108,** 177.

24 March 1951 (Director: Prof. T. Neville George)

Gower. The purpose of this excursion was to examine the stratigraphy and structure of the Upper Palaeozoic rocks in Gower. Special attention was paid to the lithology of sediments in the Oystermouth–Caswell country, particularly with regard to evidence of contemporary brecciation in the 'pseudo-breccias' of Mumbles Head, selective dolomitisation, and indications of contemporary erosion and segregation of clay lenses on some of the bedding-planes of the *Dibunophyllum* Zone.

In Caswell Bay the party devoted much time to the calcite-mudstones at the base of the Upper *Caninia* Zone. The evidence they provide of their peculiar conditions of sedimentation was shown by the pitted character of the uppermost bed of *Caninia* Oolite on which they rest, and by the recurrent evidence of contemporaneous sliding indicated by crumpled bed-planes. Some of the limestones showing rapid variations in thickness are clearly composed of slumped masses of mudstone, partly fragmented while in a caked condition, in which the angularity of the contained fragments is the result of auto-brecciation during sliding and not of erosional re-working. Some of the slumped beds of mudstones are broken along sharp fractures at the front of a plunging mass which is nosing into underlying layers, and it is evident that such beds must have been relatively well consolidated at the time of sliding.

In general, the mudstones provide evidence of an appreciable angle of slope of the floor of sedimentation, and in a number of their features they do not suggest the still placidity of protected lagoonal environments. Moreover, in some of their more minute characters they give indication of organic origin in being composed of pellet-rocks and of algal mud (as Wood has suggested), and most of them should not be regarded as chemical precipitates, laid down under calcite-pan conditions.

The relations of the overlying crinoidal limestones to the calcite mudstones are, in places, opposed to the view that the mudstones are simply to be regarded as the first shallow deposits of a transgressive Upper Avonian sea. Notably, the lowest layers of crinoidal limestones do not offer merely a sharp lithological contrast to the underlying beds, but also they contain derived and eroded fragments of mudstone in their lowest layers. There are, indeed, strong lithological indications of a significant non-sequence above the calcite-mudstone group, and since the group, as a whole, contains beds of oolite not significantly different from much of the underlying *Caninia* Oolite, it may well be the case that the group is to be regarded as running with the *Caninia* Oolite and not with the overlying crinoidal limestones, and that it is to be looked upon as the last stage of shallowing of the uppermost Tournaisian beds.

The contrasting general sequence between Mewslade and Rhossili received some attention—in particular the mid-Avonian beds in Fall—and the hint of continuity of sedimentation provided by the junction of the *Caninia* Oolite with the Upper *Caninia* Zone was noted as a further indication of the place of the calcite-mudstone group.

At *Rhossili* the contact of the Lower Limestone Shales with the Old Red Sandstone was examined in some detail. The upward decrease in sandy and gritty layers, and the passage into the more calcareous shales, were noted. Both may point to lithological transition, though no marine fossils were discovered in the uppermost quartz-conglomerates.

In the traverse across Cefn Bryn the general structural geology of Gower was seen in bird's-eye view, the details being supplemented by the clear exposures of small-scale folding and differential tear-faulting in both the eastern and western coastal outcrops.

25 March 1951 (morning) (Director: W. B. Evans)

Port Talbot and Bridgend. The party proceeded by the coast road via Neath, to Port Talbot, whence the road was followed which leads north, into the coalfield, as far as the village of Pontrhydyfen. Near here the topographic features produced by the sandstones and shales of the Pennant Series were pointed out. The party returned to Port Talbot by the same route, stopping to examine typical sections of Pennant sandstone, of the lithologically-identical Llynfi Rock, and of the quartzitic 'Cockshot Rock'. A longer stop was made at the Eagle Brickpit, Cwmavon, where several small overthrusts were noted at a horizon a little above the Six-Feet Seam (near the base of the *Similis-Pulchra* Zone). Such thrusts, with associated folding in the incompetent beds, are frequently developed in this part of the succession.

Mr. Howell Francis pointed out some of the problems of the Quarella Sandstone and described the outcrops.

Next the party visited a brick-pit near Aberkenfig where the measures between the Red Vein and the Amman Marine Band were exposed, the base of the *Similis-Pulchra* Zone and the upper part of the *Modiolaris* Zone. Incompetent structures on a large scale, involving wedge-faulting and much repetition of the Amman Marine Band, were examined.

(B) CARDIFF DISTRICT

25 March 1951 (afternoon) (Director: Miss E. Richards)

Sutton and Southerndown. After lunching at Sutton, the party proceeded to the foreshore, where a brief account of the geological history of the area was given by the Director.

Near Sutton, members examined low coastal cliffs of the Carboniferous Limestone, which is exceedingly fossiliferous. The bedding-planes were seen to be covered with large specimens of *Caninia cylindrica*, *Chonetes destinezi*, *Michelinia grandis* and *Syringothyris cuspidata*, indicative of the C. Zone. Resting in depressions in the Carboniferous Limestone are patches of limestone-conglomerate of Triassic age.

Walking eastwards towards the dry ravine of Pant-y-Slade, the party stopped to study the oncoming deposits of the Lias, resting with little apparent discordance on the Limestone. The Sutton Stone, the lower component of the littoral Lias, was seen to be conglomeratic at the base, and to pass up into a massive cream limestone. Above the Sutton Stone, the Southerndown Beds, which are thicker and less massive, consist of breccias or conglomerates composed of small pebbles of chert and limestone-fragments. These littoral deposits have yielded fossils indicative of the *angulata* Zone and the *bucklandi* Zone, while, towards the east, they pass into Liassic Shales and limestone of ordinary type. A short distance to the east of Pant-y-Slade, the Sutton Stone suddenly increases in thickness where it is banked against a Carboniferous Limestone cliff.

A short walk along the cliff brought the party to a point commanding a good view of the cliffs at Seamouth. These were seen to be made up of Liassic limestones and shales of normal character, dipping gently southwards. In these beds, at the foot of the cliff, fossils of the *bucklandi* Zone were found and these included *Coroniceras*, and other Arietids, as well as large specimens of *Gryphaea* and other lamellibranchs. These strata have been subjected to post-Liassic faulting. At the south-eastern end of the bay an excellent example of a reversed fault was seen, the Carboniferous Limestone and overlying Sutton Beds having been thrust over Lias of normal type. Beneath the steeply-inclined fault-plane the Liassic strata have been thrown into very sharp, minor folds.

After tea at Southerndown the party left by coach for Headquarters at the Grand Hotel, Cardiff.

26 March 1951 (Director: Mr. R. C. K. Blundell)

Eastern End of the South Wales Coalfield. The party left Cardiff by coach, travelling eastwards along the southern edge of the coalfield. The rocks along this part of the route consist, mainly, of Old Red Sandstone marls, with occasional inliers of Silurian. One such inlier, at Rumney, on the line of the Usk–Cardiff anticlinal belt, was noted in passing. On reaching the River Ebbw, the route turned northwards, following the river valley into the coalfield, where the first stop was made at Risca. Here, in spite of the bad visibility due to the low cloud-base, it was just possible to distinguish the successive scarps of the Old Red Sandstone grits, the Carboniferous Limestone and the Pennant Sandstone which, together with the intervening shale-hollows, form the extreme south-eastern margin of the coalfield. Also the feature formed by the Pennant Sandstone could be seen to transgress across the lower ground of the Lower Coal Series and rest on the ridge formed by the Millstone Grit and Carboniferous Limestone. This topographical expression of the intra-Coal Measures unconformity provoked some discussion between the President, Director and members.

From Risca the route continued along the Ebbw Valley to Crumlin in the central part of the main syncline of the coalfield, and thence eastwards, along the Glyn Valley, to near Pontypool on the East Crop. Here fish-remains were collected from the basal shales of the Lower Coal Series, and old opencast workings for ironstones were noted. From higher shales, above the Old Coal (the lowest seam to be worked in the area), non-marine lamellibranchs of the *Anthraconauta subovata–A. candela* group were collected. Still higher mudstones from above the next important seam, the Meadow Vein, yielded a few Productids which indicated the presence of the Amman marine-band.

From the high ground near Pontypool the Director pointed out the major topographical features; in particular, the main Usk anticline and the successive scarps of various harder beds in the Upper Carboniferous.

After lunch at Pontypool the party continued northwards along the western side of the rejuvenated Afon Lwyd Valley. This stream was crossed at Blaenavon, where its diminutive size was pointed out. From Millstone Grit Shales on the eastern side of the town specimens of *Lingula* were obtained, together with plant remains, including *Lyginopteris hoeninghausi*.

Farther north, the high moorland area of the Blorenge was crossed and a descent made into the low ground of the Old Red Sandstone marls. Unfortunately low clouds and intermittent rain prevented this part of the journey from being seen at its best.

The route now turned westwards along the Clydach Valley where, after a stop to search for plant-remains in the Carboniferous Limestone, the capture of the headwaters of the Afon Lwyd by the River Clydach was noted.

Tea was taken at Brynmawr, after which the journey was continued westwards, along the North Crop of the coalfield, to Tredegar, and then southwards, along the Sirhowy Valley. Just south of Tredegar a stop was made to see the Tredegar landslip and the Director drew attention to the presence of numbers of flat, semi-circular benches on the valley sides which were regarded as ancient landslips. Also he pointed out the very close relationship between the prevalence of the landslips and the outcrop of the Middle Pennant Group. Farther south, a stop was made near Blackwood, to collect fossils from the shales of the Upper Coal Series. Many specimens of non-marine lamellibranchs of the *Anthraconauta tenuis* group were obtained. From Blackwood the route continued southwards, via the Rhymney Valley and across the South Crop of the coalfield, back to Cardiff.

27 March 1951 (Director: Professor J. G. C. Anderson)

Neighbourhood of Cardiff and Penarth. From Cardiff the party travelled northwards, through Llandaff, along the west side of the Taff Valley, noting the wide terraces cut by the river. The first stop was made at a large disused quarry 1¼ miles NW. of Llandaff, to examine red conglomerates and sandstones ('Radyr Stone'), forming part of the local Basal Beds of the Triassic. These beds are not unlike some of those of the underlying Old Red Sandstone, but may be distinguished by the presence, in them, of fragments of Carboniferous Limestone.

The next stop was on high ground, immediately west of Radyr, to examine extensive glacial sands and gravels. These have a strongly-developed hummocky form, with kame-like ridges and 'kettle-hole' depressions.

In places the gravels contain many pebbles of Pennant Sandstone and mark the terminal moraine of ice which moved southwards off the South Wales Coalfield.

From Radyr the party proceeded westwards to a quarry, in conglomerate, two-thirds of a mile SW. of Pentyrch, with quartzite pebbles forming the top of the Old Red Sandstone. From this quarry a traverse was made northwards, through Pentyrch, across the Carboniferous Limestone, Millstone Grit and Lower Coal Series, to the steep scarp of Pennant Sandstone forming the south face of Garth Hill. All these beds dip northwards at 30°–40° into the Coalfield. Much of the Carboniferous Limestone is dolomitised and few fossils have been preserved except in the uppermost beds. These beds belong to the S_2 Zone, as the D-Zones are cut out by overlap of the Millstone Grit.

On the return journey to Cardiff the party passed through the gorge, near Taff's Well, which has been cut by the river in the Carboniferous Limestone. This gap provides one of the main outlets from the South Wales Coalfield to the sea. Attention was drawn to the large dolomite quarries on its west side, but time did not permit of a visit.

The party lunched in the Old College Refectory in Cardiff and then proceeded by coach southwards, to the shore of the Bristol Channel at Swanbridge. The members then walked across to Sully Island (accessible on foot only at low tide) and examined a very fine exposure of the Triassic-Carboniferous unconformity at the south-east corner of the island.

After returning to the mainland, the party walked eastwards along the shore, across Triassic sandstones, marls and sandy, cream-coloured limestones broken by diagrammatically-displayed minor faults. At the west end of St. Mary's Well Bay a complex fault-zone was crossed which has the general effect of a thrust, along which the Triassic strata to the west have been pushed over easterly-dipping black Rhaetic shales.

Continuing eastwards, the members were able to examine, in St. Mary's Well and Lavernock Bays, the white marls and limestones of the 'White Lias', the 'Ostrea Limestones' at the base of the Lias proper, and the limestones and shales of the *planorbis*, *johnstoni* and *angulata* Zones of the Lower Lias. From these beds many members were able to collect zonal and other fossils. In Lavernock Bay the dip flattens, and then becomes south-westerly, so that the dark Lavernock Shales (*angulata* Zone), the highest beds observed, lie in a shallow but clearly-displayed syncline.

After the members had returned to the coach at St. Mary's Well Bay the President moved a vote of thanks to the local Directors and Secretary. The party then proceeded to Cardiff where most of the members caught the 5.55 p.m. train for Paddington.

REFERENCES

BLUNDELL, R. C. K. 1952. The Succession and Structure of the North-Eastern Area of the South Wales Coalfield. *Quart. Journ. Geol. Soc. Lond.*, **107**, 307.

COX, A. H., T. F. SIBLY & A. E. TRUEMAN. 1920. The Geology of the Cardiff District. *Proc. Geol. Assoc.*, **31**.

DIXEY, F. & T. F. SIBLY. The Carboniferous Limestone Series on the south-eastern margin of the South Wales Coalfield. *Quart. Journ. Geol. Soc. Lond.*, **lxxiii**, III.

MOORE, L. R. 1948. The Sequence and Structure of the southern portion of the East Crop of the South Wales Coalfield. *Quart. Journ. Geol. Soc. Lond.*, **103**, 261.

PRINGLE, J. & T. N. GEORGE. 1948. British Regional Geology—South Wales. *Mem. Geol. Surv.*

ROBERTSON, T. 1927. The Geology of the South Wales Coalfield, Part II, the country around Abergavenny. *Mem. Geol. Surv.* 2nd edition.

STRAHAN A. AND OTHERS. 1904. The Geology of the South Wales Coalfield. Part VI. The country around Bridgend. *Mem. Geol. Surv.*

TRUEMAN, A. E. 1922. The Liassic Rocks of Glamorgan. *Proc. Geol. Assoc.*, **33**, 254–84.

Field Meeting at Keston, Downe, Kent, and Visit to the Darwin Memorial Rooms at Downe House

Saturday, 20 June 1953

Report by J. N. CARRECK

Directors: A. G. Davis and J. N. Carreck

with

Notes on some Holocene Chalk Rainwashes at Cudham and Keston, near Downe, Kent

by M. P. KERNEY and J. N. CARRECK

Received 29 October 1953

TWENTY-FIVE MEMBERS attended the meeting. At 2.17 p.m. the majority of them left Bromley North, and on ascending the dip-slope of the Blackheath Beds, crossed a river valley, at Bromley South, to Keston War Memorial, where the remaining members were awaiting them. After seeing the near-by post-mill, dated 1716, the combined party walked across Keston Common, noting the small boggy valley running northward, immediately east of the mill, which originally formed the western defence of a probable Iron Age promontory fort, and then visited the well-known Keston Bog, due to orange Eocene clays occurring within three feet of the surface. The stratigraphical position of these clays is uncertain. They are said to belong to the Woolwich Beds, but may be an argillaceous development of the Blackheath Beds, as suggested by Lovis (1951). The bog vegetation chiefly consists of mosses (*Sphagnum* spp.), with Cotton Grass (*Eriophorum*) and Sundew (*Drosera*), and here Charles Darwin obtained specimens of the latter when preparing his book on Insectivorous Plants. A good account of the bog, and its flora, has been published by Lovis (1951).

Members continued southward, to the upper and middle Keston Ponds and to 'Caesar's Well', a spring at *c.* 420 ft. O.D., probably thrown out by a clay horizon in the Woolwich Beds or the Blackheath Beds. In addition to the upper and middle ponds on the common, there is a lower pond, on private property; the middle pond is an old flooded gravel pit. Mr. Davis informs the writer that at the northern end of the upper pond, where the bank is now covered by concrete, a band of shelly clay was formerly exposed, just below water-level. The clay contained finely-comminuted shells of *Corbicula* sp., and obviously formed part of the Woolwich Beds, or possibly the Blackheath Beds. The spring at Caesar's Well is the source of the stream which flows northward, through the ponds, to Bromley South, where it is known as the 'Ravensbourne'. In fact, this stream is merely a tributary of the true River Ravensbourne, an atrophied consequent stream now rising at Hayes, but with a bifid valley-feature extending up the North Downs to near Worm's Heath and Tatsfield (Leach, 1916).

The valley running northward from Caesar's Well, and containing the ponds and stream, was pointed out to the party as forming the eastern defence of the promontory fort, and immediately south-west of the well, at the top of a vertical face of Blackheath Beds, members were shown a transverse section through the southern defence of the fort, an artificial bank or vallum. Attention was then drawn to the triangular form of the fort, protected on the west and east by boggy valleys and on the south by a bank with a flanking ditch, or fosse (O'Neil, 1933). In an abandoned gravel-pit, south-west of the well, the party examined a section in Blackheath Beds, and an account was given of the 'quartzite' pebbles occurring here, and elsewhere, in these beds. The origin of these pebbles of quartzitic sandstone has been discussed by Baker (1920), who finds that they have not been derived from Palaeozoic rocks as has sometimes been supposed, but from the Woolwich and Reading Beds. After walking westward along the bank of the promontory fort, members continued on the Blackheath Beds over Holwood Hill, passing 'Caesar's Camp' of probable Iron Age date, and the famous Wilberforce Oak.

Descending the escarpment of the Lower London Tertiaries, the party crossed the Vale of Keston before following a dry Chalk valley to the Downe House estate, the home of Charles Darwin from 1842 to 1882, which is situated on a Chalk plateau-feature covered by Clay-with-Flints. Members were shown the field of Great Pucklands in which Darwin carried out many experiments on the formation of soil by earthworms; the famous Sandwalk, where the naturalist used to consider problems arising from his researches, and Great House Meadow, the name of which recalls the fact that Downe House was known as the 'Great House' in the eighteenth century.

On the lawn of Downe House members saw the 'Worm Stone', used for measuring the rate at which stones lying on soil are buried by the action of worms (Darwin, H., 1901). In the grounds Mr. Davis read a short paper on the geological work of Charles Darwin, and the remainder of the afternoon was spent in examining the Memorial Rooms of Downe House, by courtesy of Dr. O. J. R. Howarth. The house and grounds are now the property of the British Association, having been given and endowed by the late Sir

George Buckston Browne, F.R.C.S., in 1929. The Old Study, now furnished as it was during Darwin's lifetime, is of particular interest because it was here that the 'Origin of Species' was written.

Leaving Downe House, members walked to Downe village for tea, where Dr. G. W. Himus proposed a vote of thanks to the Directors, and to Miss M. W. Reed, who acted as Field Secretary for the meeting.

Since time precluded a visit to some sections in Holocene rainwashes at Cudham and Keston, a description of these is given as an appendix to this report.

REFERENCES

MAPS. One-inch Topographical New Popular Edition, Sheet 171; One-inch Geological, Sheet 271, N.S. (Dartford); Sheet 6, O.S.

BAKER, H. A. 1920. On the Quartzite Pebbles of the Oldhaven (Blackheath) Beds of the southern part of the London Basin. *Geol. Mag.*, **57**, 62–70.

DARWIN, C. 1897. The Formation of vegetable mould through the action of worms. . . . London. Particularly pp. 139–43, 248, and 301–5.

———, F. (ed.) 1888. Life and Letters of Charles Darwin. London.

———, H. 1901. On the small vertical movements of a stone laid on the surface of the ground. *Proc. Roy. Soc.*, **68**, 253–61.

———, W. E. & W. Whitaker. 1892. Excursion to Downe. . . . *Proc. Geol. Assoc.*, **12**, 393–5.

DIBLEY, G. E. & A. S. KENNARD. 1909. Excursion to Hayes and Keston. *Ibid.*, **21**, 33–5.

HOWARTH, O. J. R. & E. K. 1933. A history of Darwin's parish, Downe, Kent. Southampton. Particularly Chapters I & IX.

KEITH, A. 1953. Sidelights on Darwin's home—Downe House. *Ann. Roy. Coll. Surgeons Eng.*, **12**, no. 3, 197–207.

LEACH, A. L. 1916. Geological and Geographical notes on the Ravensbourne Valley. *Proc. Geol. Assoc.*, **27**, 139–46.

———. 1937. Visit to Downe House. . . . *Ibid.*, **48**, 326–7.

LOVIS, J. D. 1951. A Preliminary account of the vegetation of the ponds and bog on Keston Common, Kent. *Proc. Croydon Nat. Hist. & Sci. Soc.*, **12**, 60–8.

O'NEIL, B. H. ST. J. 1933. The promontory fort on Keston Common. *Archaeologia Cantiana*, **45**, 124–8.

Notes on some Holocene Chalk Rainwashes at Cudham and Keston, near Downe, Kent

by M. P. KERNEY and J. N. CARRECK

THE RECENT discovery of three chalk rainwashes in the Cudham area, yielding molluscan faunas, is of interest as being a first record of such deposits in this neighbourhood. Two lie on the slopes of the deep dry valley which passes northward between Cudham and Single Street, crosses the

High Elms estate at Farnborough, and finally enters the Cray valley at Orpington. The other lies in a small tributary valley leading from the one already mentioned.

The first of these deposits is exposed in roadside cuttings at 500 ft. O.D., on Berry's Hill, Cudham, about half a mile west-south-west of Cudham Church (Grid Reference 51/438596). A typical section shows up to about 4 ft. of chalky wash, resting on a pure white angular chalk-rubble. The latter contains almost no argillaceous material, and may possibly be Coombe Rock. A similar deposit, sometimes of considerable thickness, has been noted in other parts of the area, and since it can be seen to lie upon the Chalk escarpment at Polhill, near Chevening, and at Shorehill, Kemsing, it must be later than that feature (Leach, 1921). No organic remains have yet been found in it.

The rainwash just described yielded thirty-one species of mollusca which are tabulated below. The fauna is essentially of woodland-type, and gives evidence of climatic conditions much wetter than those of the present. Such forms as *Acme fusca*, *Vortex lapicida*, and *Arianta arbustorum*, all of which require damp and shade in their habitats, have certainly died out in the vicinity, and could never survive, today, on the parched hillside above. This is not merely due to clearance of trees by man, since woodlands that still occur on the neighbouring slopes are too dry to support them. Probably *Acme fusca* is extinct for many miles. This snail flourished during the post-Glacial Rainfall Maximum of Neolithic times (Atlantic), but is a waning species at present. *Clausilia rolphii* is extremely rare in a fossil state, but is known from a few Early Holocene deposits in North Kent.

Such Roman and post-Roman immigrants as *Helix aspersa* Müller, *Monacha cantiana* (Montagu), *Helicella virgata* (Da Costa) and *H. caperata* (Montagu), are absent from the rainwash, though all live close by. There is little doubt that the deposit is a pre-Roman one, and may be of considerable age, but in the absence of further evidence this age is uncertain. Remains of some small mammals, found in the deposit, are listed below.

The second rainwash examined is exposed in a cutting made into the bank on the east side of Newbarn Lane, Cudham. The site is a little over half a mile south of Cudham Church, at about 470 ft. O.D., and lies almost on the floor of the dry valley (Grid Reference 51/444590). The section shows up to about 5 ft. of very white, homogeneous rainwash, with little admixture of argillaceous material, and at one point this can be seen to overlie chalk rubble (?Coombe Rock). Flints are somewhat scarce. Such a deposit probably accumulated over a short period of time, perhaps to be thought of as a few years rather than centuries, since the absence of contained humic material suggests that little or no vegetation had time to develop on the deposit during its accumulation.

In the fauna of this deposit, mollusca are fairly common, twenty-eight species being tabulated in the list. This assemblage is markedly different from the first. Xerophiles and open grassland forms such as *Helicella itala*, *Trichia hispida* var. *nana* Jeffreys, *Pupilla muscorum*, *Vertigo pygmaea*, and *Cecilioides acicula* predominate throughout. The few woodland forms tend to be restricted to the very base of the deposit. These include one example of *Acme fusca*. Two complete specimens of *Cepaea nemoralis* are noteworthy for their size, one measuring 25 mm. in breadth and the other 24.5 mm. in breadth. This is decidedly larger than the average for modern Kentish specimens.

Certainly this deposit is much younger than the Berry's Hill rainwash. *Helix aspersa* and *Monacha cantiana* are both present, and indicate a post-Roman date. It is noteworthy that *Helicella virgata* (Da Costa) and *H. caperata* (Montagu) are not found. These two xerophiles, now abundant in all Chalk districts of south-east England, came into the area only a few centuries ago. The activities of man in clearing woodland, together with decreased rainfall, have been beneficial to them, whilst many of the old woodland species are on the wane. Probably this deposit is of Medieval date, and may be correlated with the known period of increased rainfall which occurred in the thirteenth and fourteenth centuries. It is doubtful, however, if heavy rain alone would normally result in the formation of a rainwash unless the surface of the hillside had previously been broken, as, for example, by cultivation, or by the felling of trees. Judging from the presence of woodland species at the base of the deposit, the latter may well have occurred here.

At Blackbush Shaw, a quarter of a mile north-east of Berry's Green, and half a mile south-south-west of Cudham Church (Grid Reference 51/441592), another rainwash has been found. The deposit occurs at the base of a chalky bank in a hazel wood, at about 500 ft. O.D. It lies on the eastern side of a small dry chalk valley leading south-westward from the main valley in which the other two Cudham rainwashes occur. A small pit was dug in the wood, to a depth of three feet, and showed impure chalk wash, probably extending below the base of the section. Samples obtained from the base of the pit yielded the organic remains listed below. The molluscan assemblage, of thirty-two species, is predominantly a grassland one, almost identical with that from Newbarn Lane. The same critical species are present, and we may regard the two deposits as of the same age. A single fragment of *Helix pomatia* was found. Although this snail has lived in south-east England since Neolithic times, and still survives precariously, close by, very few fossil records are known. Its distribution at the present day is problematical. *Oxychilus helveticus*, *Clausilia rolphii* and *Azeca goodalli* are also noteworthy.

FAUNAL LISTS	1	2	3
MAMMALIA			
Sorex cf. *araneus* Linné	*		
Clethrionomys glareolus (Schreber)	*		
Apodemus sylvaticus (Linné)			*
Bos? sp. indet.			*
MOLLUSCA			
Pomatias elegans (Müller)	12	41	60
Acme fusca (Montagu)	11	1	
Carychium tridentatum (Risso)	187	15	18
Vertigo pygmaea (Draparnaud)	3	39	10
Pupilla muscorum (Linné)	1	81	19
Vallonia costata (Müller)	27	75	9
V. excentrica Sterki	12	1	1
Acanthinula aculeata (Müller)	8	2	3
Cecilioides acicula (Müller)	1	58	16
Cochlicopa lubrica (Müller)	14	10	22
Azeca goodalli (Férussac)			1
Ena obscura (Müller)			2
Punctum pygmaeum (Draparnaud)	3	3	10
Discus rotundatus (Müller)	92	28	62
Arion sp.	Ab.	Ab.	Ab.
Clausilia bidentata (Ström)	15	17	4
C. rolphii Turton	3		2
Marpessa laminata (Montagu)	6	8	6
Helicella itala (Linné)	13	58	30
Monacha cantiana (Montagu)		14	5
Trichia hispida (Linné)	8	97	81
T. striolata (C. Pfeiffer)	17	1	1
Vortex lapicida (Linné)	8	2	2
Arianta arbustorum (Linné)	7		
Cepaea hortensis (Müller)	3		
C. nemoralis (Linné)	4	4	3
Helix pomatia Linné			1
H. aspersa Müller		4	3
Euconulus fulvus (Müller)	1		
Retinella radiatula (Alder)	1		2
R. pura (Alder)	5	6	54
R. nitidula (Draparnaud)	16	9	38
Oxychilus helveticus (Blum)			1
O. cellarius (Müller)	5	4	5
Vitrea crystallina (Müller)	14	30	46
Vitrina pellucida (Müller)	1	1	
Limax sp.	6	53	55

1 = Berry's Hill. 2 = Newbarn Lane. 3 = Blackbush Shaw. Ab. = Abundant. * = Species represented in deposit. Numerals denote numbers of specimens found.

Sorex is represented by a fragmentary palate showing the left pm^3, m^1, and m^2, and a left mandibular ramus showing m_1, m_2, and m_3. *Clethrionomys* is represented by five isolated molars, and part of a left mandibular ramus showing m_1, and the incisor. The only example of *Apodemus* is a right m^3, and that of ? *Bos* is merely a fragment of a cheek tooth.

In 1951 a note on some temporary sections in a chalk rainwash of Roman age at Blackness Lane, Keston (Grid Reference 51/416628), was published by Mr. A. G. Davis and one of the present writers, and a faunal list was included (Davis & Carreck, 1951). Two additional species of mollusca may now be recorded, and a fuller mammalian list may be given.

MAMMALIA

Microtus agrestis (Linné), right m_1; *Apodemus sylvaticus* (Linné), left mandibular ramus with m_1; *Sus scrofa* Linné, 1st or 2nd lower incisor; *Bos* sp., right m_2, and a metatarsal cannon bone; ? *Ovis aries* Linné, bone fragment, probably from shaft of humerus.

MOLLUSCA

Retinella radiatula (Alder), 1 example; *R. pura* (Alder), 31 examples.

The molluscan faunule of the Blackness Lane rainwash is most closely comparable with those of the Newbarn Lane and Blackbush Shaw deposits, but a few species suggest the presence of some woodland at the time of formation of the Keston deposit. As mentioned in the 1951 report, the Blackness Lane rainwash rests not directly on the chalk, but on chalk-rubble in a fine, buff-coloured loamy matrix, apparently devoid of fossils. This is probably identical with that seen below the rainwashes at Newbarn Lane and Berry's Hill, Cudham, and appears to be a Late Pleistocene solifluction-deposit, similar to that occurring also beneath rainwash at Halling in the Medway Valley.

ACKNOWLEDGMENTS

The writers wish to thank Mr. A. G. Davis for his constant help and advice, and Miss M. W. Reed for her invaluable part in the field work.

REFERENCES

Davis, A. G. & J. N. Carreck. 1951. Note on rainwash at Blackness Lane, Keston. *London Naturalist*, no. 30, 36–7.

Leach, A. L. 1921. Report of an Excursion to the North Downs in Kent. *Proc. Geol. Assoc.*, **32**, pp. 38–9.

Summer Field Meeting in North-West Ireland with an Introductory Note on the Geology

9–25 September 1953

Report by W. S. PITCHER and R. L. CHEESMAN

Directors: W. S. Pitcher and R. L. Cheesman; assisted by J. G. C. Anderson, T. Neville George, H. H. Read, R. M. Shackleton and M. K. Akaad, G. G. Lemon, D. H. Oswald, I. C. Pande, C. F. Tozer and E. H. T. Whitten.

Received 17 February 1954

CONTENTS

1. INTRODUCTION AND SYNOPSIS OF GEOLOGY ... ... *page* 345
2. DAILY ITINERARIES 351
EXPLANATION OF PLATE 370
REFERENCES 370

---

1. INTRODUCTION AND SYNOPSIS OF GEOLOGY

THE MEETING aimed to introduce members to work in progress on various aspects of the solid geology of North-West Ireland. It was emphasised by the Directors that no complete statement of this geology was then possible, and that, necessarily, many problems still awaited solution.

Despite the attractive nature of the rocks, detailed investigations had been neglected, in large measure, since the publication of the Survey Memoirs in 1890 and 1891. Nevertheless certain re-interpretations of the Donegal Granite were given by Grenville Cole (especially 1902) and by G. Andrew (1928), while a new phase in the research began with the detailed stratigraphic studies of W. J. McCallien (1935, 1936, 1937) and J. J. Hartley (1938). Owing to the war, however, it was not until 1946 that systematic surveys were commenced. At present the Donegal Granite, and its envelope, is being studied by a research team drawn mainly from the Imperial College of Science and Technology, University of London, and directed by Professor H. H. Read. The stratigraphy of certain parts of the Dalradian and Moinian successions is being elucidated by Professor J. G. C. Anderson of the University College of South Wales and Monmouthshire, by Professor R. M. Shackleton of the University of Liverpool, and by their respective associates. On the other hand, the overlying Carboniferous strata are under investigation by a team from the University of Glasgow, led by Professor T. Neville George.

The greater part of County Donegal (Fig. 1) is composed of metamorphosed sediments which are the equivalent of the Dalradian and Moinian rocks of Scotland. In a similar way to these latter, they are cut by granites of presumed 'Caledonian' age, comprising the large mass referred to as the Donegal Granite, and the smaller granitic masses of Barnesmore and Fanad Head. To the south of the county the metamorphic rocks are unconformably overlain by Carboniferous strata which extend far into the adjoining counties.

(a) **The Dalradian of North-West Donegal.** A thick series of Dalradian metasediments forms the envelope of the Donegal Granite. The lithology of the sediments is varied and well-defined, while the numerous metadolerite sills show a great uniformity of rock-type. Although these basic sills were intruded prior to the folding and regional metamorphism, yet narrow zones of thermal metamorphism still survive at the contacts of the thicker sills.

Detailed successions have been established in several areas. On the north-west margin of the Donegal Granite, within the synclinal structure of the Cresslough area (McCall, 1954), a thick and varied succession appears to follow upwards from that determined farther to the south-west, in the anticline of the Lower Gweebarra Estuary (Iyengar, Pitcher & Read, 1954). A different group of rocks, characterised by a remarkable Boulder Bed (Plate 11A), occurs along the south-east margin of the Granite. The succession containing this Boulder Bed, which is best exposed in Glencolumbkille (Anderson, 1954) and Fanad, is the stratigraphical equivalent of the Islay succession of Scotland.

Where the two distinct groups are in contact, at the ends of the elongate mass of the Donegal Granite, the relationship is of a mechanical nature, recalling the similar separation of the Islay and Ballachulish successions in Argyll. It appears that these rock-groups are themselves separated from the lithologically distinct rocks of Central Donegal by an important fault-zone of NE.–SW. trend (Fig. 1), now under investigation by Professor Read, Professor Shackleton and Dr. Pitcher.

Throughout the greater part of North-West Donegal the rocks are strongly folded on typically Caledonoid axes with consistent overfolding to the north-west. On the western seaboard, however, the trend of fold-axes swings east–west, giving rise to a significant feature marked throughout the west of Ireland. During the fold-movements a regional metamorphism advanced the pelitic rocks to biotite-muscovite-schists which contain garnet locally. Widespread retrograde changes are indicated by the replacement of this garnet by chlorite and sometimes by the growth of new chlorite. This diaphthoresis may be connected with the powerful thrusting which complicates the fold-structures.

A superimposed thermal metamorphism resulted from the emplacement

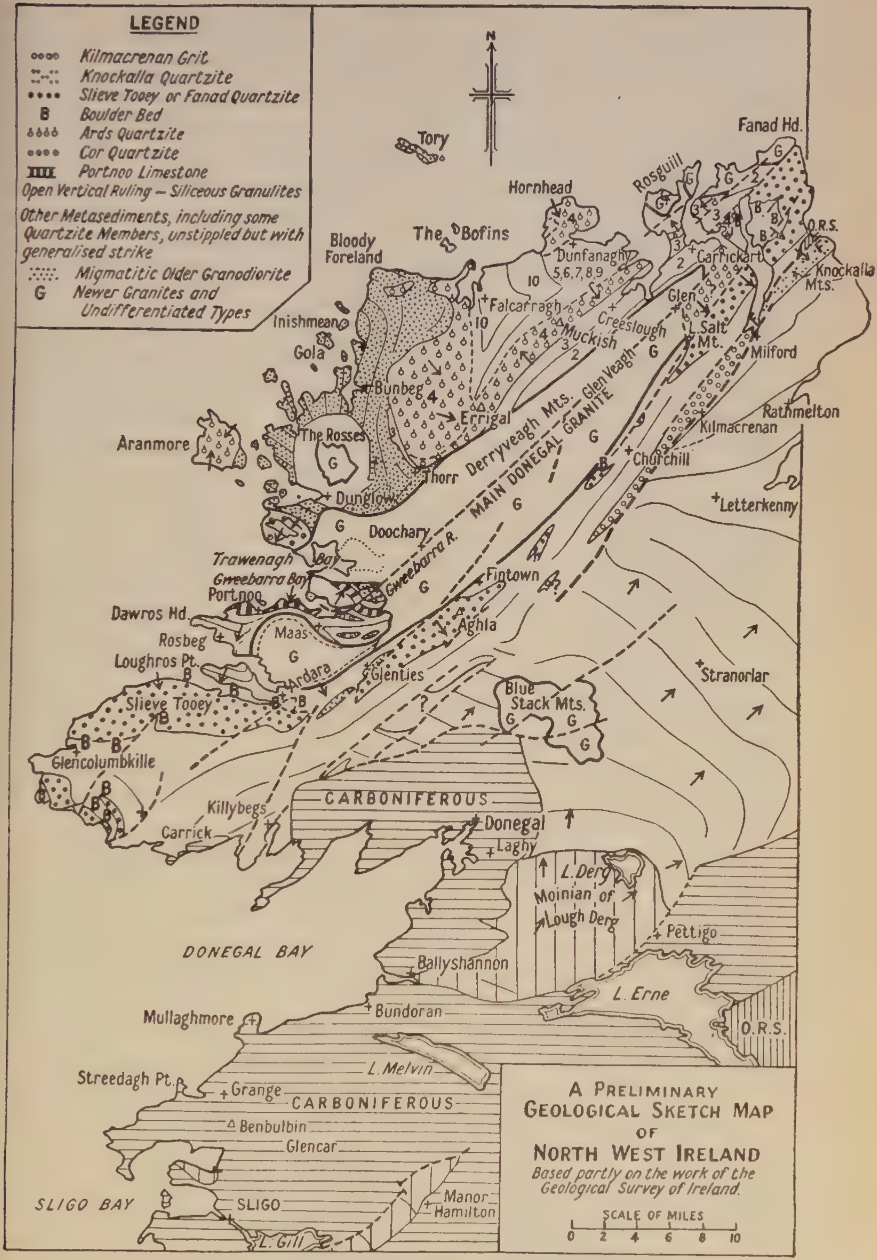


Fig. 1. Geological sketch-map of NW. Ireland

of the granitic rocks. It is shown by zoned aureoles with mineral-assemblages characterised by sillimanite (sporadically associated with kyanite), garnet, staurolite and andalusite. Shear stresses accompanied the emplacement, and both granites and hornfels are strongly deformed. A large number of tear-faults, parallel to the strike, were initiated at a late stage in the structural history. Especially they are concentrated in a zone extending along the south-eastern boundary of the Donegal Granite.

Numerous minor structures can be related to this long metamorphic history. Thus, in Dawros Head, R. S. Mithal has shown that four superimposed structural patterns clearly reflect the same number of tectonic phases which are, in order of age, the folding, thrusting, emplacement of the granite and a later shearing. Extensive references to the metamorphism and structure are made in many of the works listed in the bibliography.

(b) **The Donegal Granite.** The Donegal Granite is a comprehensive name for a complex of granitic rocks, the numerous components of which fall naturally into two groups: (i) an early tonalitic migmatite, intruded by (ii) a series of more homogeneous and clearly magmatic granites. The first has been called the *Older Granite* or *Granodiorite* and the second, collectively, the *Newer Granites* (Gindy, 1953; Pitcher, 1953A).

The Older Granodiorite occupies much of the north-western seaboard (Fig. 1). Over a considerable area it contains numerous orientated enclaves of metasediment and metadolerite by means of which original sedimentary horizons can be traced through the complex. This phenomenon has been referred to as the preservation of a ghost stratigraphy (Pitcher, 1953A). Adjacent to such relict masses the mixed and streaky rocks are erratically variable in mineral composition, but over wider areas E. H. T. Whitten has shown that they are progressively enriched in microcline and quartz towards a focal point (Gola Island) which also appears to be the structural centre of the Older Granite complex.

The extensive outcrop of the Newer Granites can be divided into a main mass, extending between Doochary and Glen (Fig. 1), and the three western lobes of Ardara, Trawenagh Bay and the Rosses. Work by M. K. Akaad shows that to the north of Ardara a composite granodiorite diapir has shouldered aside the country rocks, and in so doing has deformed the latter and its own outer mantle of tonalitic hybrids. By contrast, the homogeneous granites of the Rosses are disposed in the form of a cross-cutting ring-complex which was emplaced by a mechanism akin to that of cauldron-subsidence (Pitcher, 1953B). The rectilinear outline of its internal and external contacts resulted from the control of the bounding fractures by early-formed joint-planes. Both of these circular structures are cut across by a component of the main mass, of which the Trawenagh Bay Granite (Gindy, 1953A) forms a lobe-like termination. The latter differs from the main mass in its comparative homogeneity and paucity of cataclastic structures. Probably it is the equivalent, in time and type, of the central intrusion of the Rosses.

The main mass, which is some twenty-six miles long, is elongated in the NE.–SW. strike of the country rocks. Though heterogeneous, clearly it is one unit and it exhibits linear and often sheeted contacts both with the metasediments and the Older Granodiorite. The pale-coloured muscovite-granites which form a common rock-type within the sheeted contact-zones are frequently pegmatitic, and to the north of Glenties, where the main mass plunges at a low angle under a sedimentary cover, great pegmatitic sheets tongue upwards into the roof (Iyengar, Pitcher & Read, 1953). Inside this pegmatitic fringe R. L. Cheesman has shown that while the biotite-granite encloses lines of fragments of the various country rocks, and these retain their relative positions far out into the mass, yet the associated granites are here comparatively homogeneous and show little evidence of contamination.

The Barnsbeg Gap provides a typical section across the northern part of the mass and is being studied by C. F. Tozer and I. C. Pande. Here a medial line, which is marked by a NE.–SW. fault-zone following the hollows of the Gweebarra and Glen Veagh, approximately separates a banded complex of grey granites from a more continuous and homogeneous area of pinkish and coarser-grained granite. The latter predominates on the north-west side of Glen Veagh and continues far to the south-west, eventually merging into the granite lobe of Trawenagh Bay. The south-eastern complex consists of bands of granite, differing somewhat in composition and texture, which trend parallel to the main contact.

A most remarkable feature of the main mass, as a whole, is the presence of small aligned strips of country rock which are confined to certain narrow zones. The latter are parallel to the length of the mass, and each is characterised by a specific assemblage of enclosures. Associated particularly with the north-western portion of the mass are lumps of the migmatitic quartz-diorite (the Old Granodiorite), trains of which extend for the entire length of the mass. These dioritic enclosures, together with strips of grey granite, and various granitised metasediments and metadolerites, are felspathised, softened and streaked out, and injected with pegmatitic material in such a way as to form belts of dioritic and granitic fluxion-gneiss. Even the more normal granites are diversified by the widespread occurrence of thin, streaky bands of granitic material which differ from the more normal granites in both grain-size and biotite-content. These planar structures are uniformly steep.

Beside the many irregular pegmatitic streaks and lenses, there are more discrete pegmatites and aplites which, together with a suite of felsite dykes, mark a late stage in the plutonic activity. Evidence of an even later stage, such as a feeble sulphide-mineralisation, is exceedingly scanty.

The various structures of the main mass of the Donegal Granite point to forceful magmatic intrusion along an important structural break, and probably in a number of consecutive pulses. Contacts between granite types are often seen but these contacts are generally discontinuous and welded, the earlier member having been rendered plastic and mobile. Thus the time-intervals between injections were small and probably few of the granite masses entirely consolidated before further emplacement took place. It seems unlikely that intrusion was vertical. On the contrary, the train of fragments of country rock which originated in the south-west suggests that there was a considerable horizontal component in the direction of flow.

During and after consolidation the main mass was strongly deformed, especially in the contact-zones. Today a marked foliation is apparent, but cataclasis is not always an important feature and, as within the sheared hornfelses, retrograde changes are generally absent, suggesting that deformation was thus effected whilst the rocks were still at a high temperature.

Adding diversity to the main study are basic masses which involve a remarkable complexity of rock-types ranging from peridotites, through appinitic amphibolites to hybrid diorites (Gindy, 1951B; Iyengar, Pitcher & Read, 1954; M. K. Akaad). There are numerous dykes of hornblende-lamprophyre, porphyrite and porphyry, some of which are markedly xenolithic (Gindy, 1951A; Pitcher & Read, 1953; R. S. Mithal). In addition, there are several vent-like areas of explosion-breccia (R. L. Cheesman, R. S. Mithal). It is concluded that these, and other phenomena, are related to the one granitic event.

In the course of a primary gravity survey of the north of Ireland (Cook & Murphy, 1952), results obtained from two traverses across the Donegal Granite indicate that more detailed work might enable the form of this body to be determined, in depth.

(c) **The Barnesmore Granite.** Walker & Leedal (1954) have ascribed a pre-Carboniferous age to the granite mass which forms the Blue Stack Mountains. It consists of several distinct intrusions, the latest and most fine-grained of which occurs as a sheeted complex forming arch-like structures within the main granite. These structures are attributed to the subsidence of internal blocks of the latter. A variable suite of intermediate dykes followed the emplacement of the granite and members of the suite are associated with several vents containing both brecciated granite and country rocks.

(d) **The Moinian of South-West Donegal and Sligo.** The siliceous granulites which underlie the Carboniferous rocks in the area between Lough Derg and Ballyshannon, and even farther south in the Ox Mountains, have been shown by J. G. C. Anderson (1948) and G. G. Lemon (1952) to be the equivalent of the Moinian rocks of Scotland. These rocks exhibit a high grade of metamorphism accompanied, in many areas, by injection and partial mobilisation. North of Lough Derg they are followed conformably by dominantly pelitic strata correlated with the lower part of the Dalradian (= Upper Moinian of Anderson, 1953). The intensity of metamorphism, as indicated by the presence of kyanite and staurolite, becomes progressively less northwards, in the pelitic schists of Central Donegal. Basic rocks are represented by garnet-amphibolites, accompanied by serpentines of uncertain age in the Sligo area.

(e) **The Carboniferous Rocks.** Locally, especially in a wide outcrop east of Lough Erne, the metamorphic rocks are unconformably overlain by the coarse-grained arenaceous beds of the Old Red Sandstone (e.g. Wilson, 1953). In general, however, the Carboniferous rocks completely overstep the thick Old Red Sandstone and rest with major unconformity on the Moinian or Dalradian. The history of the area involves the submergence of an ancient peneplain beneath a transgressive Dinantian sea. Nowhere do Tournaisian rocks appear, the transgression having commenced during Upper-Caninian times (Wright, 1913; Delepine, 1949; Oswald, 1952; George, 1953).

(f) **The Tertiary Dyke-Swarm.** While basaltic dykes are represented throughout the county they are especially numerous in a swarm of northwesterly trend which cuts across the Donegal Granite. On the other hand pitchstones and felsites are associated with olivine-dolerites and crinanites in the Barnesmore area (Walker & Leedal, 1954, 236).

Although no mention has been made of either glaciological or geomorphological aspects of Donegal, both constitute considerable chapters in its geological history (*v.* J. K. Charlesworth, 1924, 1953). W.S.P.

2. DAILY ITINERARIES

In this record of the meeting, sufficient detail has been included to make it serve as a general field guide. With a few exceptions, localities mentioned are marked on the one-inch sheets of the Ordnance Survey of Ireland, the appropriate numbers of which appear in brackets after the titles of the daily reports.

Thursday, 10 September

The President, Mrs. Himus and twenty-five members of the Association were met at Londonderry by the Director, Dr. W. S. Pitcher, and the Secretary, Mr. R. L. Cheesman. After lunch the party motored to Massinass Hotel, Creeslough, enjoying the general views *en route*.

Friday, 11 September (Director: Prof. R. M. Shackleton)

The Fanad Peninsula (Sheets Nos. 4 & 5). The day was spent in examining the Islay succession and its relation to that of North-West Donegal. The local succession is as follows:

Pelitic schists
Cranford Limestone and Dolomite
Fanad Quartzite
Boulder Bed
Limestone
Dark phyllite and limestone: fault or slide
Ards Quartzite
Ards Black Pelitic Schist

Through Carrowkeel the road extending north-eastward from Upper Town lies in a valley which marks the position of the Cranford Limestone. This important horizon immediately succeeds the Fanad (Islay) Quartzite, which is exposed in the hills to the north of the road. At the cross-roads beyond Fanad House the party followed the track to Ballymastocker Bay. Outcrops of the Cranford Limestone were examined before crossing the sand-dunes to shore-exposures of a boulder-conglomerate thought to be of Old Red Sandstone age. This is preserved on the northern and down-throw-side of a major fault, the scarp of which forms the face of the Knockalla Mountain.

Returning to the coach, the party motored to a point one mile S. 10° E. of Kindrum where exposures of the Islay Limestone were examined in the fields to the south of a lane leading into the hills. After following this lane, the party ascended through the hamlet of Carrowkeel, and proceeded northwards across the fields to outcrops of the Fanad Quartzite, a uniform white quartzite which locally contains an impersistent boulder-horizon. Striking westwards to the coast road opposite Croaghan Island, the route lay across Croaghan Hill (Triangulation Point 366 ft.), on which the Boulder Bed appears beneath the Quartzite. Excellent exposures show sub-angular boulders, up to a foot or more in diameter, scattered in a fine-grained siliceous matrix. The boulders are chiefly composed of a coarse pink granite, but quartzite, a yellowish limestone and a few other metamorphic rocks occur.

After a sandwich lunch in Kindrum the party motored westwards into the isolated peninsula forming the western part of Fanad. Along the lane flanking Cashelmore Hill are outcrops of black schists (Ards Black Schists) which give way, south-eastwards, to those of the Ards Quartzite. A quarter of a mile south of Cashelmore a valley of NE.–SW. trend marks a considerable structural break, for the Islay Limestone forms the opposing ridge and underlies an oval outlier of the Boulder Bed. The latter is exposed on Crocknaseeagh Hill, north of Ballyhork North, from which vantage-point members obtained an extensive view of this part of Donegal, with its intricate system of sea-loughs.

Motoring and walking to the Mulroy ferry, the party spent anxious moments shouting across the channel. Eventually a small boat with a female crew made several somewhat perilous crossings in increasingly bad weather. The motor-coach was rejoined at Carrickart.

Saturday, 12 September

(Directors: Prof. R. M. Shackleton and Dr. W. S. Pitcher)

Creeslough and Dunfanaghy (Sheets Nos. 4 & 10). The main object of the day was the traverse of a thick series of Dalradian strata lying beyond the north-western margin of the Donegal Granite. Within the synclinal structure the succession established by Dr. G. J. H. McCall (1953), is as follows:

10. Falcarragh Pelitic Schists
9. Port Dolomitic Limestone
8. Sessiagh Banded Quartzite
7. Marble Hill Dolomitic Limestone
6. Clonmass Banded Quartzite
5. Clonmass Dolomitic Limestone
4. Ards Quartzite
3. Ards Black Pelitic Schists
2. Creeslough Group
1. Lackagh Quartzite

The party motored to Lackagh Bridge where the lowest member in the succession, the Lackagh Quartzite, possesses a sharp contact with the main mass of the Donegal Granite. To the north of the bridge the rodded quartzite, with its variable sheets of granite and pegmatite, is well exposed in roadside-sections; to the south, sillimanite-garnet-schists occur as rafts in the granite.

The return to Creeslough was by way of a road running beside the long narrow valley of the Duntally River, which latter marks the side of one of the thick calcareous horizons within the Creeslough Schists. This marble was examined in the old railway-cutting adjacent to the level-crossing where biotite porphyroblasts were observed to characterise the pelitic intercalations. Near the road-junction immediately south of Creeslough, banded semi-pelitic schists exhibit sporadic biotite-flakes, a fact which determines an outer zone of the thermal aureole of the Donegal Granite.

By kind permission of the Guardian of the Franciscan Priory, members were able to view the beach-section south of Ards House. This provided excellent exposures in the Ards Black Schists, which are pyritous, dip south, and, as a result of increasing intercalations of quartzitic bands, pass into the Ards Quartzite. This transition was well seen around Ards Point, while beneath a prominent metadolerite sill, current-bedding shows that the sequence is inverted. It was noted that the sill had retained its chilled margin despite inversion and metamorphism. Returning to the main road at Cashelmore, the ridge of the Ards Quartzite could be seen to merge into the Mountains of Muckish and Aghla Beg.

Beyond Ballymore, road-side quarries were visited in the Sessiagh Banded Quartzite, and nearer to Dunfanaghy, at the end of Sessiagh Lough, the Marble Hill Dolomite was found to be well-exposed in the old quarries behind the garage. After collecting from the tremolite-marbles, the party assembled to study details of the view seen across Sessiagh Lough; particularly a steep cliff in the flat-lying Sessiagh group, overlain by the thick Knockfada Sill.

The traverse then continued through Dunfanaghy to the Horn Head Bridge. Here the party alighted from the coach and walked north-westward to Claggan and thence to the coast at Micky's Hole, on the west side of the peninsula of Horn Head. The Ards Quartzite forms the greater part of the peninsula but in the neighbourhood of Claggan, schists and metadolerites of the Falcarragh Group appear above this horizon and, at the Hole, a cliff-section shows that these schists are in tectonic contact with the Quartzite. The latter is progressively deformed as the flat-lying thrust-plane is approached and platy, lineated quartz-mylonites abut against paper-thin schists. A metadolerite sill is intensely sheared and folded where it enters the thrust-zone. Approximately 1500 ft. of the succession has been cut out by this dislocation, the outcrop of which follows a sinuous course for some miles until eventually it passes north of Dunfanaghy. It may be expected to account for the absence of a large part of the Creeslough succession much farther to the west.

After examining some of the felsite sills, the party walked south along the summit of the cliff. Near the top of the rise pre-orogenic spotted hornfelses appear at the contact of a large metadolerite sill (The Mam). The sill itself shows a distinct rhythmic banding, which appears to be graded locally. Following upon considerable discussion of these matters, the members crossed Croaghadara and returned to the coach.

A hearty vote of thanks was accorded to Professor Shackleton for his leadership.

Sunday, 13 September (Director: Dr. W. S. Pitcher)

The Barnes Gap and Kilmacrenan (Sheet No. 10). The traverse of the northern part of the main mass of the Donegal Granite commenced at a point on the main Kilmacrenan Road one mile south of the Lackagh Bridge Road junction. In a small quarry, and in outcrops on both sides of a small stream, schists with thin green calc-silicate bands are associated with limestones. These rocks are strongly lineated and the many dykes of granite and pegmatite are markedly deformed, developing shear-structures and boudinage-structures. The contact with the main granite is not seen clearly, but can be inferred to be sharp and straight, the boundary forming a conspicuous topographic feature. Here the granite is extremely variable in both texture and composition, being banded, streaky, and in part pegmatitic. In a quarry opening from the main road, and some 300 yds. from the contact, the party was able to study the remarkable banded rocks occurring within this contact-zone. Similar phenomena were observed in the disused railway-cutting near Drumnaraw School, but beyond the school it was noted that the banding is due to a simpler association of coarse-grained and medium-grained granite which dies out away from the contact. From here as far as the Owencarrow Valley (the extension of Glen Veagh) the plutonic rocks are far more homogeneous, with little evidence of banding and inclusions, but with prominent shear-foliation.

After crossing the Gweebarra-Glen Veagh fault-line at New Bridge, the coach followed the Glen Road for one and a half miles as far as Derriscligh Wood. In this wood a large road-side quarry exposes a greyish-medium-grained granite enclosing large masses, of which one consists of a coarse dioritic rock and another is calc-silicate flags. Many complex relationships of the granite-types were seen, and the discussion as to their nature continued when the party returned to the main Kilmacrenan road. Here, on the same line of strike, and just north of the viaduct, road-side exposures revealed the heterogeneity of this particular zone of the main mass. Especially evident are the angular fragments of dioritic rocks, and lense-like masses of metadolerite.

Immediately south of the viaduct dolerite dykes occupy NW.–SE. joint-planes. Probably their presence explains the marked topographic feature of the Barnes Gap. Everywhere such dykes are less resistant to weathering than is the granite.

A walk south-eastwards through the Gap afforded many opportunities for examination of the granite. Where the railway again meets the road, vertical cuttings show screens of country rock which maintain the regional attitude. Here dark semi-pelitic hornfelses are accompanied by a marble which is partly converted into fibrous wollastonite and studded with large grossular garnets. Where the country opens out, an excellent north-easterly view was obtained of the large screen of schist on Crockmore which underlies an outer sheet of a lighter-coloured and often garnetiferous granite. Farther along the road the railway line passes into a cutting which shows numerous screens with relatively shallow dips to the south-east. Emerging on to an embankment, the party was able to observe that the country rocks of the main contact are sheeted in a regular manner with a pale, garnetiferous granite. Garnet can be seen in some layers of schists at the contact, while kyanite and staurolite are easily distinguished in thin sections of these rocks. Lunch was taken in the large roadside quarry at the entrance to Barnes Gap.

The afternoon was spent in examining the Kilmacrenan Grit. From the well-known Donegal Shrine of Doon Rock members walked north-westward to the disused railway-track, along which there are many exposures of the high-sheared Kilmacrenan Grit that lies immediately above a series of black, striped phyllites.

In view of the time only one other locality was visited, which lay near the Kilmacrenan–Churchill road, one mile south-west of the Roman Catholic Chapel. Immediately south of the road, and near the footbridge over the Leannan River, outcrops of the Kilmacrenan Grit show especially well-developed graded-bedding which demonstrates the inversion of the associated strata.

Monday, 14 September

(Directors: Dr. W. S. Pitcher and Dr. E. H. T. Whitten)

Gweedore and Thorr (Sheets Nos. 9 and 15). The objective was a study of the older member of the Donegal Series, the *Older Granite* or *Granodiorite.*

After travelling westwards via Falcarragh to Gortahork, the coach followed the Bloody Foreland road. West of Gortahork the contacts of the schists and the Bloody Foreland (Ards) Quartzite were pointed out. The road crosses the well-exposed eastern extension of the Older Granite which is intruded into Quartzite at this locality. Near Magheraroarty Post Office excellent views were obtained of Horn Head, Tory Island, the Bofins, and the fine recurved spit extending across Ballyness Bay. Due north of Bloody Foreland Mountain a roadside-quarry shows the granite-quartzite contact, with numerous very irregular granitic veins and sheets which cut the quartzite and have irregular and gradational contacts suggestive of replacement. The Director explained that the main contact with the coarse-grained marginal granite is sharp and angular, as if produced by a stoping mechanism. From the main road through Knockfola the party walked to Rinardalliff Point where wave-swept reefs expose foliated Older Granite, with aligned feldspars and occasional mafic xenoliths. Of principal interest were the numerous angular xenoliths of quartzite (with schistose fabrics partially obliterated by recrystallisation), the random orientation of which resulted from magmatic flow of granite.

Farther to the south the road passes through the remarkable morainic boulder-sand accumulation which is piled on the south side of Bloody Foreland Mountain. After turning westwards from the main road in Carrick, the party proceeded to a point near the shore east of Inishmeane. Here a leucocratic potash-granite (The Gola Granite) represents a facies of the Older Granite which was progressively enriched in potash felspar and quartz and so contrasts with the granodiorite (with high colour-index) of Rinardalliff and the Bunbeg and Thorr areas with which it is structurally continuous. These rocks are interpreted as indicating an early stage in the genesis of potash granite from granodiorite.

After a hurried lunch at 'Stratford's', Magheraclogher, near Bunbeg Post Office, some members collected from the calc-silicate hornfelses, with multitudes of weathered-out grossular (-idocrase) rhombic dodecahedra, from a locality north of Clady River and south-west of the church. These hornfelses are part of the most northerly example of the large metasedimentary xenoliths in the Older Granite. (E.H.T.W.)

After lunch the party motored through Crolly and, turning off along the secondary road to Thorr, met a serious obstacle in the presence of a low bridge situated on a sharp bend. The coach negotiated this successfully, however, and set down the party at Meenawheel Chapel. Along the road running south to Lough Keel are sillimanite-hornfelses of the Thorr Pelitic Group which form a ridge to the east, while behind this lies the quartzite (Ards Quartzite) Mountain of Crogan More. Immediately west of the road, and half a mile from the outlet of Lough Keel, the extensive mobilisation of the pelitic hornfelses was clearly seen near the main contact with the Older Granodiorite. After returning to the road, the party continued southwards to Thorr School, and then westwards to Meencorwick where the contact-rocks were seen again.

Across the Owenator, and along the Dunglow road, the large metasedimentary rafts were examined which occur about a hundred yards beyond the bridge. Nearly a mile farther west, in Ardveen, members took the only minor road to the north and, immediately they reached the high ground, were able to study an area of mixed granitic and pelitic rocks. Among many interesting features, the large size of the sillimanite crystals, occurring in pod-like groups, attracted much attention. Returning to the Dunglow road, a track about a hundred yards east of the road-junction led the party southwards through numerous exposures of the Older Granodiorite, with its xenoliths, schlieren and cross-cutting microgranite sheets.

Between Loughs Nanillan and Nagilly the path lay across a huge raft consisting of marble and metadolerite and, on the shore around the southern lobe of Lough Nagilly, members collected from extensive skarns in which idocrase was a conspicuous calc-silicate mineral. Crossing the lough by a somewhat unstable bridge, another minor road led the party back to Ardveen. Exposures of metasediments proved to be banded siliceous granulites contrasting with those seen in Meencorwick and Ardveen. They form part of the Meenatotan Banded Group and, despite their presence as mere fragments enclosed in granodioritic rocks, a natural line can still be drawn between the two lithological types.

Farther to the west and particularly in the unfenced field immediately west of the road-junction nearest Lettercaugh School, a contact of the older rocks with one of the medium-grained Newer Granites of the Rosses, *G1A*, is found with ease. Search above the School reveals a contact of this *G1A*-type with a coarser-grained variety of granite, *G2*.

As the coach was unable to negotiate the minor road from Lough Anure, the party walked to that locality, arriving late and weary at the new rendezvous. (W.S.P.)

Tuesday, 15 September (Director: Dr. W. S. Pitcher)

The Rosses (Sheet No. 15). Before entering the Rosses the party motored to Dunlewy and from the road which rises behind Errigal obtained a fine view of the Derryveagh Mountains that form the main mass of the Donegal Granite. The great corrie of the Poisoned Glen forms a spectacular feature, with the moraine-dammed lakes of Dunlewy and Nacung lying at its foot.

Proceeding by Gweedore into the Rosses, the route followed the main road from Crolly through Annagary and Kincasslagh to Keadew, and from there via Meenbannad to Dunglow. The rocks of this broad coastal platform are exceedingly well exposed, having been stripped of their peat cover by the local population. The first stop was made half a mile beyond Annagary where, by examining road-side exposures near the sharp turn in the road, members were able to locate the outer boundary of the ring-complex, where a medium-grained granite, *G1A*, is in contact with the Older Granodiorite. Next, after passing through Mullaghduff, a quarry was visited at a point three-quarters of a mile beyond the inn and near the junction of a lane and the road. Here the entire width, and the contacts, of a wide porphyry dyke were examined, including dark chilled marginal rocks and apophyses.

After lunch in Kincasslagh the main contact was again examined at the road-side one hundred yards north-east of the junction with the lane which leads to Balcruit Roman Catholic Chapel. Here the medium-grained granite-type *G1*, shows a steep outward contact with the older rocks, a narrow pegmatitic fringe clearly marking the boundary. After crossing Keadew Strand this same contact was located again, without difficulty, in fields which occur at the point where the road passes on to the plateau.

On retraversing the Strand, the coach followed the southerly road to the cross-roads near Meenbannad School. After examining the coarse granite, type *G2*, the party walked eastwards along the old railway-track as far as the beginning of the first cutting. Near the old cattle-track gate a porphyry dyke intrudes *G2*, but fails to cross the contact into the central granite, *G3*. A swarm of porphyry dykes was examined by turning north for a hundred yards along the minor road at the end of the cutting. Some of these dykes contain joint-blocks of their host-rock, granite *G2*, suggesting that the emplacement of the dykes was controlled by the master-joint planes. By following the same road, south of the railway-track, and turning first left and then immediately right along a farm-track, the contact between *G2* and *G3* was found, in the right-hand field.

On returning to the Meenbannad cross-roads, the traverse continued southwards into the townland of Sheskinarone and to a point a quarter of a mile south of the secondary road to Meenbannad. Near the first cottage a rough track was followed, about some 100 yds. to the east, where the inner junction of *G3* with *G2* was recognised by its chilled contact. Due south of this point, at the top of the rise, and adjacent to a prominent mass of vein-quartz, a beryl-greisen was hammered vigorously by members, who collected many fine specimens.

This being the last locality to be visited, the coach made all speed to Ardara, via Dunglow and Doochary.

Wednesday, 16 September (Director: Dr. W. S. Pitcher)

Maas (Sheet No. 15). The Dalradian rocks lying to the south of the Gweebarra estuary, and between Maas and Derrylogan, were invaded by three different types of granite which superimposed contrasted structures and metamorphic effects upon the folded and regionally metamorphosed sediments. The succession of strata in the area is as follows:

Cleengort Pelites
Portnoo Limestone
Maas Semipelites
Mulnamin Calc-silicate Flags
Mulnamin Siliceous Flags
Cor Quartzite

Beginning the traverse at the Gweebarra bridge the party followed the lane leading into the townland of Cleengort, on the north face of the prominent hill of that name. At the entrance to the lane, a road-cutting and quarry expose bedded marbles of the Port Noo Limestone. Farther along the lane cuttings show deformed metadolerite sills in calcareous rocks, the contact zones of the former being converted to friable hornblende-schists. Continuing north-eastwards across numerous exposures of highly-mobilised sillimanite-hornfelses belonging to the Cleengort Pelites, a contact with granitic rocks was crossed near the highest point in the lane. Much enthusiasm and discussion was aroused by the extensive exposures of migmatite which flank the path. Then followed a rapid walk through the scattered hamlet of Cleengort, to the edge of the cultivated land, where a pale medium-grained granite, belonging to the main mass, cuts across the migmatites.

Returning to a point near the contact between hornfels and migmatite, the party followed the best possible route south-eastwards, across rough country, passing off the Cleengort Pelites and across outcrops of the Portnoo Limestone. Within the Maas Semipelites, and lying on both sides of an overgrown gorse-fenced path, the appinitic amphibolite of Mulnamin More next claimed the party's attention.

A small path led the party into the Mulnamin Valley. The prominent Ranny Point sill of metadolerite lies in the upper part of the Mulnamin Calc-silicate Flags. After crossing it, a series of scarp-features were seen to be produced by differential weathering of the alternating bands of siliceous granulite and calc-schist within the Flags. There are five or six hard ribs throughout the 800 ft. of this particular series, each becoming more siliceous towards the base. A characteristic creamy-coloured marble forms the lowest horizon of this group and was seen in a quarry south-west of the Mulnamin lane, at a point 250 yds. from its junction with the main coast road. This lane was followed to where the Mulnamin stream provided a section in the Mulnamin Siliceous Flags. A few hundred yards farther on lunch was taken at the primitive licensed house in Mulnamin.

On following the twisting road southwards the Calc-silicate Flags, with their siliceous horizons, and the Ranny Point Sill, were identified in the steeper limb of the Mulnamin Anticline. North of the bridge over the River Maas the Director pointed out both the change of dip, and the presence of fragments of the creamy limestone, in a small quarry. This demonstrates the presence of a tight syncline on the flank of the major anticline, a structure appreciated much more readily farther to the north-east, on Mulnamin Hill. Below the farm west of the junction of the lane which leads to Lough Nagarnaman the Calc-silicate Flags are vertical in attitude, much-sheared and highly-attenuated; in the gorge below the Bridge the Mulnamin Siliceous Flags lie to the north of the creamy limestone which is itself immediately adjacent to Cor Quartzite. The Director explained that these complications were the result of close folding and thrusting on the northern margin of the Crocknadreeavarh block of Quartzite.

Along the road flanking Crocknadreeavarh, calc-silicate rocks were seen on the southern side of the quartzite ridge where they are well exposed in quarries. Round the sharp bend in the lane the low plain of the Ardara granite pluton came into view, when its strongly-foliated tonalitic contact-facies was seen beyond the junction with the westerly farm-track. The latter was followed to its termination, where members crossed the wire fence into a field on the point of the ridge. In this field the Director demonstrated the juxtaposition of one of the siliceous ribs within the Calc-silicate

Flags and the upper part of the Mulnamin Siliceous Flags and suggested that this mechanical junction was 'healed' by the thermal effects of the Ardara pluton. Following this line across the next fence, the creamy limestone appeared in its natural position between them. Both Professor H. H. Read and Dr. Pitcher believed these tight and broken folds were the result of the 'shouldering' action of the Ardara pluton.

The coach was rejoined at the road-junction by Letterilly House.

Thursday, 17 September (Director: M. K. Akaad)

Ardara (Sheets Nos. 15 and 23). The study of the Ardara Pluton began with a drive from Ardara to Narin. The Director pointed out the topographic expression of the rock-types. Thus, at the Owenea Bridge the outer coarse tonalite was seen to form higher ground than the inner granodiorite. At the Narin cross-roads a similar relationship was shown to hold for the northern side of the pluton, and also a good view was obtained of the arcuate range of hills formed by the contact-hornfelses. Leaving the coach at this locality, members examined the sharp contact between the foliated tonalite and the mobilised sillimanite-cordierite hornfelses. Locally, a thin zone of quartz-tourmaline rock marks this boundary.

The party then crossed to the larger triangular area, between the main roads, where a lamprophyre dyke exhibits a boudinage-structure caused by the dilation of the hornfelses during emplacement of the pluton. Similar boudins, formed from siliceous bands and a metadolerite sill, were examined in the small roadside-quarry 200 yds. up the hill from Clogher School. Here the party ascended Clooney Hill, quickly crossing the inner sillimanite zone of the pelitic hornfelses on to andalusite-bearing rocks, the structures of which indicate a condition of plasticity and limited mobilisation during the thermal changes. Farther across the hill, and away from the granite margin, the andalusite-hornfelses proved to be less affected. At the top a clear view was obtained of the pluton as a whole, as well as the arcuate outcrop of the Portnoo Limestone. Westwards, near the summit of Cashalgolen Hill, members eagerly collected from fine exposures of orientated chiastolites, after which they descended to the main road immediately east of Clooney Post Office and walked eastwards for half a mile to where the track to a small quarry leaves the northern side of the road. Here they were able to collect fine specimens from quartz-andalusite veins; 'exudates' produced during thermal metamorphism. A few yards west of the main group of houses in Clooney a grass track leads south to a prominent granite outcrop in which the main contact was clearly seen.

On arriving at Portnoo the Director pointed out the current-bedding in roadside-outcrops of marble, near the Post Office, after which the party enjoyed a sandwich lunch in beautiful weather and with a magnificent view of the Gweebarra Bay.

Motoring towards Rosbeg, a stop was made where the road approaches Pound Lough. Here loughside-exposures in pelitic phyllonites illustrated the normal regionally-metamorphosed rocks of this area. In addition, the several planar and linear elements present were described by Dr. Pitcher from the work of Dr. R. S. Mithal. A second stop, at a point on a road-bend east of Lefrin Hill, gave the party an opportunity to examine a remarkable xenolithic hornblende-'lamprophyre' which is distinctly layered, with rounded boulders of quartzite and rimmed calc-silicate fragments probably brought from horizons many thousands of feet below.

Lineated, low-grade phyllonites were seen, once again, on the beach at Rosbeg where they are cut by numerous lamprophyres and felsite dykes. The prominent chlorite-knots are pseudomorphs after garnet.

Returning to Narin, and taking the Ardara road, members were shown the typical outer tonalite near the 'Rock', a group of cottages about a quarter of a mile from the main road junction. Alighting at Kilclooney Roman Catholic Chapel, the party followed the lane to Clooney, examining numerous exposures of the xenolithic quartz-diorite on the way. Mr. Akaad illustrated the contamination of the original biotite-granodiorite, and different stages in the digestion and incorporation of the amphibolitic xenoliths which occur in numerous 'swarms'. Also he discussed the nature and cause of the marked foliation; especially the flattening of the basic patches. At Lough Killayenna the quartz-diorite exposed in the quarry was seen to be cut by a thick vein of unfoliated granodiorite and, near Clooney, outcrops of the coarse tonalite enabled a comparison to be made between the two dioritic types which form the periphery of the Ardara Pluton.

After meeting the coach at Clooney, a last stop was made, on the return to Ardara, to see the uncontaminated biotite-granodiorite which occurs half-way between Narin and Ardara.

Friday, 18 September

(Directors: M. K. Akaad and R. L. Cheesman)

Glenties and Fintown (Sheets Nos. 15 and 23). The morning was spent in examining the Mill Ponds Basic Complex and the Carbane Hill Gneiss. Motoring from Ardara towards Glenties, the party left the bus near Kilreen Post Office and walked along the main road to Donegal. In a field adjacent to the disused cemetery there are abundant dark outcrops of the massive peridotite and hornblende-peridotite which form the central core of the Complex, and in the next field to the north members examined the ultrabasic amphibolite, which is its totally-recrystallised equivalent. Proceeding westwards, after crossing the main road, outcrops of dioritised amphibolites were noted, of which rocks some were very coarse-grained, with characteristic bladed hornblendes, while others exhibited streaky or banded structures, as seen behind the farmhouse on the old Donegal road.

Returning to the coach, the party was driven to the Roman Catholic Church in Glenties, whence it followed the footpath from the rear of the church which leads upwards and through the woods. On emerging into open country the party left the path and crossed several fields near to electricity pylons. In heavy rain a successful search was made for the mylonitised fringe of the Carbane Hill Gneiss, after which, in clearing weather, members ascended Carbane Hill itself and studied the gneissose dioritic rocks *en route*. Mr. Akaad then gave a general description of the view in relation to the geology, making special reference to the mechanical nature of the base of the Slieve Tooey Quartzite, the scarp of which forms the face of the near-by mountain ridge.

After walking north-eastwards until it reached a well-defined track, the party followed this latter down to the main road, noting exposures of the several members of the Glenties Series. The bridge crossing the Stracashel stream spans a deep ravine which appears to be an incised spur on the side of the heavily-glaciated Glenties Valley. When the party had rejoined the coach on the Stranorlar road, lunch was taken in Glenties. (M.K.A.)

After leaving Glenties, the party motored along the main Ballybofey road as far as the Stracashel road. The coach was able to negotiate the latter for one mile, where the party alighted to examine a roadside-quarry in the Slieve Tooey Quartzite. Here Mr. R. L. Cheesman pointed out that not only was the quartzite contorted and somewhat crushed, but sedimentary features were not very marked, probably as a result of the proximity of the thrust-plane upon which the quartzite had ridden over the rocks of the Glenties series. It was noted that on this eastern side of the transverse Stracashel Valley, the thrust-block of quartzite had been carried farther to the north than the block which had been seen during the morning, south of Carbane Hill.

The party then walked along the road for a third of a mile and examined a small quarry in the southwardly-dipping quartzite, fifty yards north-east of the road. Here, by contrast with the previous exposure, were sedimentary features well-preserved, including excellent ripple-marks, slumping and current-bedding, all of which revealed that the beds were not inverted.

On returning to the coach the party motored back to the Ballybofey road, and along it as far as Shallogans Bridge. Here a diversion was made by way of the Derryloghan road to the turning for Doochary. From here the party examined the well-exposed, main mass of the Donegal Granite which at this locality is a sheared, somewhat banded grey rock of normal granitic composition. Particular note was made of the xenoliths or rafts of country rock preserved in the granite and which are found to occur in the same line of strike as their equivalent rock-types in the Maas succession. These rafts form the 'ghost stratigraphy' in an igneous granite, of which a study is being made by the Director. Semi-pelitic and calcareous rocks were observed along the roadside between the road-junction and the school. Behind the latter members collected from an exposure of marble, with a well-developed contact-skarn consisting of garnet, idocrase and wollastonite.

Some of the party then accompanied the Director to the top of Derkbeg Hill (1100 ft.) where the pegmatite-fringe of the granite is well seen, interdigitating with Mulnamin Calc-silicate Flags and associated meta-dolerites. From this summit not only the general geology of the area could be appreciated, but also the extent of the main granite mass. The view also included the glaciated fault-valley of the Gweebarra which extends to the head of Glenveagh, in the north-east.

Returning to the coach, the party motored back to the main road and continued eastwards towards Fintown, noting the well-developed terminal moraine at the western end of Lough Finn and the cultivated outwash-fan at the foot of the Altmore stream which descends from Aghla Mountain (quartzite).

Next, the coach proceeded to the top of Carbat Gap, on the Fintown–Doochary road, where members again examined the Donegal Granite and saw further examples of the preservation of a 'ghost stratigraphy'. The various rock-types were a continuation of those seen at Derryloghan, and in the Maas Succession, on the same strike. (R.L.C.)

During the return to Ardara Messrs. Akaad and Cheesman were accorded a hearty vote of thanks for their efficient directorship.

Saturday, 19 September (Director: Prof. J. G. C. Anderson)

Glencolumbkille (Sheet Nos. 22, 23, 30 and 31). In very wet weather the party motored southwards to Killybegs Harbour. *En route* the Director outlined the general geology, giving the succession of rocks as follows:

Carboniferous (unconformity)
Slieve Tooey Quartzite Group
Boulder Bed
Glencolumbkille Limestone Group
Killybegs Pelitic and Calcareous Group

Just before entering the built-up area of Killybegs, members alighted and descended to the beach where the Killybegs Group is represented by contorted chloritic schists with calcareous horizons. The coach continued through the town to a point a little over half a mile beyond it, where two quarries open from the northern side of the Kilcar road. Here an epidiorite sill intrudes flat-lying siliceous flags in which perfectly-preserved current bedding shows them to be inverted. In the adjacent quarry the joints of the basic rock are heavily coated with haematite, probably on account of the proximity of the Killybegs fault.

On the western side of Fintragh Bay the party left the coach again and made for the shore east of Shalwy Point, where gently-dipping fossiliferous limestones and shales of Carboniferous age were examined. The unconformity at the base of these rocks is very well exposed both west of the Point and on the cliff below the junction of two lanes of which one skirts the coast and the other leads back to the main road. Here a thick boulder-bed rests on a gently-dipping erosion-surface of schists belonging to the Killybegs Group. This deposit is exposed clearly on both sides of the second lane referred to above, and by means of which the party returned to the Kilcar road. Some 200 yds. west of this road-junction a small quarry was visited in schists which shows minor folds plunging eastwards at an angle similar to that of the plane of unconformity. The Director pointed out that post-Carboniferous movements could not be ignored in interpreting minor structures occurring in these metamorphic rocks.

After the party had lunched in Carrick, the coach followed the road along the west side of the Glen River estuary to a point one and a half miles south by west of the village. The party left the coach at the commencement of a well-defined track which eventually leads to the narrow summit-ridge of Slieve League known, locally, as the One Man's Pass. Toiling upwards in heavy rain, the party soon reached the first exposures of the steeply-dipping Slieve Tooey Quartzite when Professor Anderson explained that, at this point, the basal Boulder Bed was cut out by a thrust. On the western side of the corrie containing Croleavy Lough, blocks of this characteristic bed were seen at the side of the track, and it was explained that the party had traversed a tight syncline in the Quartzite. In the complementary anticline, pelitic and calcareous rocks of the Glencolumbkille Limestone Group were shown by numerous exposures at the head of the corrie. Where quartzitic rocks first appear again on the path, the Boulder Bed is well seen in an inverted sequence. To the west follows another tight syncline in the Quartzite, overlain, at the two main peaks of Slieve League, by small outliers of Carboniferous conglomerate. The excursion to the summit of the mountain had to be abandoned, however, in view of adverse weather, thereby causing the party to lose the magnificent view from the top of the 2000-ft. cliffs. On motoring into Glencolumbkille, some members braved heavy rain to visit fine road-side exposures in the Boulder Bed at a point 700 yds. N.10°E. of the church, after which an early return was made to Ardara.

Sunday, 20 September (Director: R. L. Cheesman)

Loughros Point (Sheet No. 23). After lunch the party proceeded by coach to the Kilcashel road-junction on the Loughros Point Road.

Walking up the Kilcashel road, the party passed several exposures of the typical southern 'phyllonites' which are garnetiferous mica-schists, reduced in grade by retrograde metamorphism, and showing the spots, or weathered holes produced by chlorite which has replaced garnet. Some 350 yds. along the road, the party turned across the fields to the left. The low hill of Drumnacrolly is a small boss of contaminated granite, probably intruded at a late stage in the plutonic history of the area. It was noted that this intrusion, approximately half a mile in diameter, had little metamorphic effect on the country rocks.

After traversing the hill, the party joined the Liskeeraghan road immediately south of the cutting. In the latter a good section of the phyllonites was seen, with complex structures, and examples of overfolding to the north. One of the early lamprophyre dykes was examined at this point.

The road was followed, across well-exposed areas of schist and phyllonite, to the townland of Liskeeraghan. North of a cliff-like feature which, according to the Director, may mark the position of an east–west thrust, the party noted the incoming of more distinctly banded schists comparable with those of Rosbeg.

At the road-junction immediately before the houses in Liskeeraghan, the party stopped to examine the 'explosion breccia' emplaced in the banded schist. The Director pointed out that this rock-type, of which several examples occurred in Loughros and in Rosbeg, here covered 400 sq. yds. Angular fragments of the local banded schist occurred in a fine-grained matrix which appeared felsitic in the field, but under the microscope was seen to be a mass of comminuted fragments of the country rock, including garnets altering to chlorite. At its edges the breccia grades rapidly into normal banded schist through a narrow zone in which the bedding is greatly contorted. The Director suggested that the mode of origin might have involved an uprush of gaseous material along a longitudinal vent which disrupted the country rock, and caused the larger fragments to fall back into the vent in a haphazard manner.

After some discussion of this phenomenon, the party moved northwards along the track, crossing a large metadolerite sill. At the end of the track, the wall was followed up the slope of Crockatee, the highest hill in the peninsula. The hill has been developed from a steeply-plunging anticline of banded schist.

Passing westwards, the Director pointed out the proximity of the main granite mass of the Ardara pluton, on the mainland about a mile away, as evidenced by the production of giant chiastolites in the schists, up to six inches in length. A pause was made for the collection of specimens.

The party reached the north coast immediately east of Long Cove and proceeded along the shore to Pollaleahy. Graded bedding in the schists on this northern limb of the anticline revealed 'younging' to the north—

contrary to the general direction in the area. The Director pointed out that the complimentary syncline lay in the Bay and that the rocks of similar nature at Rosbeg again 'younged' to the south.

At this locality the 10-ft. Raised Beach exhibits fine glacial features and the party was impressed by the deep grooves running approximately parallel to the present coast-line.

At Pollaleahy, abundant chiastolite was observed. This mineral is cut by the late strain-slip cleavage which produces a marked frilling in the schists.

The party then struck inland to rejoin the Kilcashel road and returned to the coach at the junction with the Point road.

Monday, 21 September (Director: Prof. J. G. C. Anderson)

Lough Derg (Sheets Nos. 43 and 55). In very wet weather the party motored south through Donegal and Laghy, and turned off along the main Pettigo road. The ecological change is very marked as the road passes eastwards from cultivated Carboniferous country on to the peat-covered outcrop of the Lough Derg Psammitic Group. Approximately one and three-quarter miles from the main road junction a small roadside-quarry exposes the striped siliceous granulites which form the most important lithological type in the Lough Derg rocks. After examining these, and despite the heavy rain, some members took the north-easterly lane to a point near Ballykillowen Hill where the schists of the Oughtadreen Pelitic Group appear above the Psammitic Group. Sufficient samples of the garnet-kyanite-staurolite-schists were collected for those who did not visit this exposure. On the way to Pettigo two more localities were visited. One roadside-exposure three-quarters of a mile south of Oughtdarnid provided an example of the garnet-amphibolites, and near Lough Namnamurrive a quarry in siliceous granulites and lenticular epidiorites exhibited contorted bedding which probably resulted from limited plastic flow during metamorphism.

After lunch in Pettigo, the route lay along the flooded Lough Derg road to a quarry half a mile south-east of the ferry-house on the Lough-side. Granulites with biotitic bands were seen to be extensively injected with pegmatitic material.

On returning to Pettigo, the party enjoyed a tour along the northern shores of Lough Erne, proceeding via Boa Island to Belleek. Where the causeway from the western end of the island joins the mainland a large quarry exposes shattered and slickensided fossiliferous Carboniferous Limestone, in proximity to the Pettigo fault. Numerous fossils from the same formation were collected in another quarry east of Belleck. On approaching Ballyshannon, the party inspected the lower barrage harnessing the waters of the Erne, and Professor Anderson gave a short account of the geological considerations which determined the locations of the two dam-sites. The last locality to be visited was in Ballyshannon itself where, near the County Donegal Railway Station, siliceous granulites are exposed.

The party then motored south to Sligo, which became the headquarters for the remainder of the meeting. There, on behalf of members, the President thanked Professor Anderson for his able direction, in face of extremely arduous conditions.

Tuesday, 22 September

(Directors: Prof. T. Neville George and Dr. D. H. Oswald)

Ballyshannon and Bundoran (Sheets Nos. 31, 43). The succession of Carboniferous strata in the Bundoran area is as follows:

Glenade (formerly 'Yoredale') Shale and Sandstone
Dartry Limestone
Benbulben Calp
Mullaghmore Sandstone
Bundoran Shale
Ballyshannon Limestone
Basal Beds (unconformity)

First the party visited the road-cutting on the northern side of the Erne dam, one mile east of Ballyshannon, to examine the local base of the Ballyshannon Limestone which rests unconformably on siliceous Moine granulites. The thick conglomerates of the Muckros–Shalwy ground are represented here by only 6 to 8 ft. of coarse brown dolomite carrying large angular platy fragments of granulite and pebbles of vein-quartz. The dolomite passes upwards into an arenaceous limestone which rapidly gives way to thin-bedded limestone with shales. The main outcrop of the Ballyshannon Limestone was followed westwards to the coast at Fairies Bridge, where a grey fossiliferous limestone, with *Lithostrotion* and *Daviesiella destinezi*, is exposed. At Aughrus Point there is a gradual upward transition of this limestone into the richly-fossiliferous Bundoran Shale, which was followed in the coast-section as far as Bundoran. This shale yielded a varied and well-preserved fauna suggestive of an S_1 age.

A similar gradual upward transition of the Bundoran Shale into the Mullaghmore Sandstone was observed near the mouth of the Drowes River, one and a half miles west of Bundoran. These micaceous current-bedded sandstones attain a thickness of some 600 ft., and constitute a marked break in the calcareous series throughout the Sligo area. In the continuation of this coast-section towards Mullaghmore Head the varied lithology of the beds suggests deltaic rather than truly marine deposition, and the presence of small-scale slump-structures promoted discussion.

Proceeding via Grange to Streedagh Point, the party inspected the Ballyshannon Limestone where it appears on the southern side of the Grange Fault. Abundant large caniniid corals cover the bedding-planes and project from the softer shale bands in the cliff-sections.

In the magnificent escarpment of Benbulben, which forms a background to the coastal plain, the stratigraphical succession was clearly seen from Streedagh. The main scarp is composed of shales overlain by impure limestones (the two components of the Benbulben Calp), and is capped by the massive Dartry Limestone, while its foot is aproned by a bench of Mullaghmore Sandstones. These strata form characteristic features on a scarp-front which can be followed for many miles.

Wednesday, 23 September

(Directors: Prof. T. Neville George, Dr. D. H. Oswald and G. G. Lemon)

Sligo (Sheets Nos. 43, 55). The day was devoted to a further examination of Carboniferous strata; to a rapid survey of the Moinian rocks occurring in a long inlier which extends into the Ox Mountains, and to a visit to the lead mine at Ballysadare. Proceeding via Glencar to Shanvaus Cross, about two miles west of Manor Hamilton, the party examined the coarse dolomitic beds of the lower part of the Ballyshannon Limestone, exposed in prospecting pits.

The route then followed the valley which marks the Ox Mountains Fault—a fault which throws the Dartry limestone against the Moinian ridge between Benbo Mountain and Lough Gill. An extensive and fossiliferous development of a reef-facies in the Dartry Limestone of this area was examined on the east flank of Leean Mountain, where a rich collection of fossils from bedded limestones immediately below the reef included some blastoids.

Farther south-west a halt was made in Stonepark, a mile north of Drumahaire, where kyanite-bearing siliceous granulites are exposed clearly, to the east of the road. They enclose a large lens-like body of garnet-amphibolite (metadolerite) which is extensively injected by quartzo-felspathic veins. A more semi-pelitic rock-type within the Moinian rocks was examined at roadside exposures in the townland of Castleore, three miles WNW. of Drumahaire. These rocks are highly and irregularly contorted, having been rendered plastic during metamorphism.

A mile to the west, in the townland of Correagh, outcrops of the Slishwood Serpentine were visited at a point 100 yds. north of the cross-roads. The serpentine is much-jointed and extensively veined with chrysotile asbestos, vermiculite and oxides of iron and manganese. From this locality northwards, the basic mass occupies the wide valley which traverses the Moinian ridge.

By kind permission of the Manager, Mr. Moorhead, the party was able to visit the Abbeytown Mine at Ballysadare. Mr. Moorhead and Mr. Cunningham conducted the party through the opencast workings and explained the mode of occurrence, and method of working the lead-zinc ores. The galena and blende are disseminated through coarse-grained sandy limestones within the Ballyshannon Limestone.

In the evening the President thanked Professor T. Neville George, Dr. D. H. Oswald and Mr. G. G. Lemon for their direction on the only two days of the meeting during which fossils and economic minerals could be collected. Finally, he voiced the thanks of the party to Mr. Cheesman and Dr. Pitcher for a thoroughly interesting and most efficiently organised field meeting. In replying, Dr. Pitcher expressed his gratitude to Mr. Cheesman for his effective handling of a very large part of the general arrangements. Mr. Cheesman then expressed the appreciation of the party for the efficient service provided by the Lough Swilly Bus Company and their driver, Mr. McGrory.

On Thursday, 24 September the party left Sligo for Belfast, by coach, on the *third* really fine day on the meeting.

EXPLANATION OF PLATE

A. The Boulder Bed on Croaghan Hill, Fanad. Rounded boulders of a coarse granite are set in a semi-pelitic matrix.

B. Swarm of amphibolite xenoliths in the contaminated quartz-diorite forming one of the outer zones of the Ardara Pluton. Near road south-east of Lough Fad, Kilclooney.

REFERENCES

ANDERSON, J. G. C. 1948. The occurrence of Moinian rocks in Ireland. *Quart. Journ. Geol. Soc.*, **103**, 171–90.

———. 1954. The pre-Carboniferous rocks of the Slieve League promontory, County Donegal, Eire. *Quart. Journ. Geol. Soc.*, **109**, 399–422.

ANDREW, G. 1928. Contact relations of the Donegal Granite. *Proc. Man. Lit. Phil. Soc.*, **72**, 210–19.

CHARLESWORTH, J. K. 1924. The Glacial Geology of the north-west of Ireland. *Proc. Roy. Irish. Acad.*, **36B**, 174–314.

———. 1953. The Geology of Ireland. London.

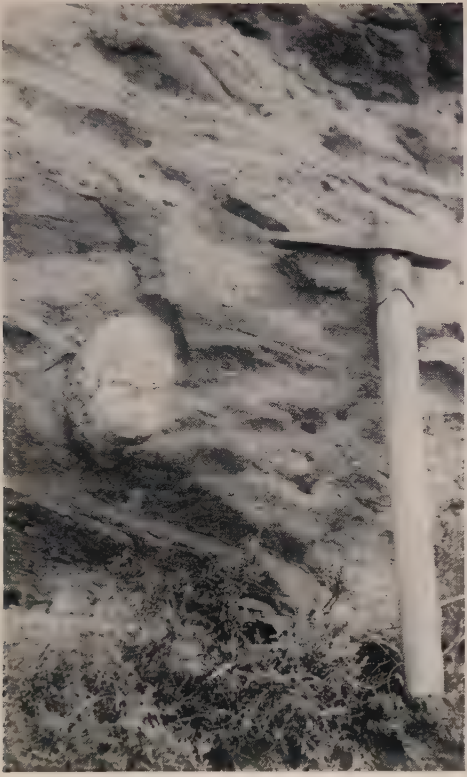
COOK, A. H.& T. MURPHY. 1952. Measurements of Gravity in Ireland. Gravity survey of Ireland north of the line Sligo-Dundalk. *Geophys. Mem. Dublin Inst. Adv. Stud.*, No. 2, Pt. 1, 1–36.

COLE, G. A. J. 1902. Composite gneisses of Boylagh, West Donegal. *Proc. Roy. Irish Acad.*, **24B**, 203–30.

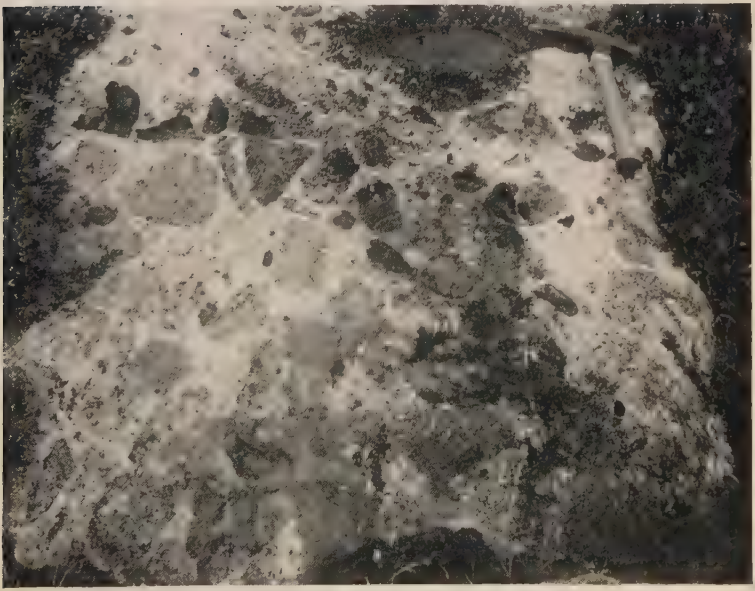
———. 1906. On a hillside in Donegal. *Sci. Prog.*, 343–60.

———. 1913. The Geology of the Mullaranny and Sligo Districts. *Proc. Geol. Assoc.*, **24**, 62–9. (Contains a geological sketch-map in colour.)

———. 1919. On the mode of occurrence and origin of the orbicular granite of Mullghderg. *Sci. Proc. Roy. Dub. Soc.*, **15**, No. 15.



A. The Boulder Bed, Croaghan Hill



B. Xenolithic quartz-diorite, Kilclooney

GINDY, A. R. 1951A. A Xenolithic Sill at Tallabrista, Co. Donegal, Ireland. *Geol. Mag.*, **88**, 55–9.

————. 1951B. The production of amphibolite and other skarn rocks from limestone at Cor, Co. Donegal. *Geol. Mag.*, **88**, 103–12.

————. 1953A. The plutonic history of the region around Trawenagh Bay, County Donegal, Eire. *Quart. Journ. Geol. Soc.*, **108**, 377–411.

————. 1953B. Progressive replacement of limestone inclusions in granite at Ballynacarrick, Co. Donegal. *Geol. Mag.*, **90**, 152–8.

GEORGE, T. N. 1953. The Lower Carboniferous rocks of north-western Ireland. *The Advancement of Science* (*Brit. Assoc.*), **37**, 65–73.

HARTLEY, J. J. 1938. The Dalradian rocks of the Sperrin Mountains and adjacent areas in Northern Ireland. *Proc. Roy. Irish Acad.*, **44B**, 141–71.

HOBSON, B. 1913. Report of an excursion to West Mayo and the Sligo District. *Proc. Geol. Assoc.*, **24**, 78–86.

HULL, E. & OTHERS. 1890. North-west and central Donegal. *Mem. Geol. Surv. Ireland.* (Contains a list of references to all earlier works.)

————. 1891. South-west Donegal. *Mem. Geol. Surv. Ireland.*

IYENGAR, S. V. P., W. S. PITCHER & H. H. READ. 1954. The plutonic history of the Maas Area, Co. Donegal. *Quart. Journ. Geol. Soc.*, **110**, 203–30.

LEEDAL, G. P. & G. P. L. WALKER. 1953. Tear Faults in Donegal, Ireland. *Geol. Mag.*, **91**, 116.

LEMON, G. C. 1952. The Moinian Inlier of Rosses Point, near Sligo, Eire. *Geol. Mag.*, **89**, 124–8.

MCCALL, G. J. H. 1953. The Dalradian geology of the Creeslough area, Co. Donegal. *Quart. Journ. Geol. Soc.*, **110**, 153–75.

MCCALLIEN, W. J. 1935. The metamorphic rocks of Inishowen, Co. Donegal. *Proc. Roy. Irish Acad.*, **42B**, 407–42.

————. 1936. A note on Dalradian pillow lavas, Strabane, Co. Tyrone. *Proc. Roy. Irish Acad.*, **43**, 13–22.

————. 1937. The geology of the Rathmullen District, Co. Donegal. *Proc. Roy. Irish Acad.*, **44B**, 45–59.

PITCHER, W. S. 1950. Calc-silicate skarn veins in the limestone of Lough Anure, Co. Donegal. *Min. Mag.*, **29**, 126–41.

————. 1953A. The migmatitic older granodiorite of Thorr District, Co. Donegal. *Quart. Journ. Geol. Soc.*, **108**, 413–46.

————. 1953B. The Rosses Granitic Ring-Complex, County Donegal, Eire. *Proc. Geol. Assoc.*, **64**, 153–82.

PITCHER, W. S. & H. H. READ. 1952. An appinitic intrusion breccia at Kilkenny, Maas, Co. Donegal. *Geol. Mag.*, **89**, 328–36.

WALKER, G. P. L. & G. P. LEEDAL. 1953. The Barnesmore Granite Complex, Co. Donegal. *Sci. Proc. Roy. Dubl. Soc.*, **26** (N.S.), 207–43.

WHITTEN, E. H. T. 1952. Cataclastic pegmatites and calc-silicate skarns near Bunbeg, Co. Donegal. *Min. Mag.*, **29**, 737–56.

————. 1954. Two arfoedsonite rhyolite intrusions from Cloghancchy, Co. Donegal, *Min. Mag.*, **30**, 393–9.

WILSON, H. E., 1953. The petrography of the Old Red Sandstone rocks of the North of Ireland. *Proc. Roy. Irish Acad.*, **55B**, 283–320.

WRIGHT, W. B. 1913. On the Lower Carboniferous succession at Bundoran in South Donegal. *Proc. Geol. Assoc.*, **62**, 70–7.

Much additional detailed information is recorded in geological theses of the Universities of London and Glasgow. Among those of the University of London still unrepresented by published work are theses by R. L. Cheesman (Loughros, 1952); R. S. Mithal (Dawros Head, 1952) and E. H. T. Whitten (Gweedore, 1953); of those in the University of Glasgow is that by D. H. Oswald (Between the Ox Mountains and Donegal Bay, 1952).

Field Meeting at Abberley, Worcestershire

MIDLAND GROUP

12 September 1953

Report by the Director: P. A. GARRETT

Received 25 January 1954

THE PARTY, which numbered forty-five, assembled at Knightsford Bridge on the Worcester–Bromyard Road where the River Teme breaks through the ridge of Lower Palaeozoic rocks which marks the Malvern–Abberley axis. This ridge is composed of steeply-dipping and much-folded and faulted-Silurian rocks, with occasional cappings of gently-dipping Haffield Breccia—possibly the equivalent of the Clent Breccia of south Staffordshire. To the east it is separated by a steeply-dipping boundary (which may be an unconformity, but which, in places, is certainly faulted) from the great Triassic basin of deposition now occupied by the valley of the River Severn. To the west, dips rapidly become gentle and the main outcrop of the Old Red Sandstone occurs.

The first exposures visited were in the road- and railway-cuttings to the north and west of Knightwick Station. In the railway-cutting Keuper Marl was seen to be faulted against pale-coloured Keuper Sandstone typical of the top of the formation. However, most of the Keuper Sandstone exposed here, and also well seen in the road-cutting, consists of alternating beds of coarse red sandstone and red breccias. The very irregular nature of the Triassic land-surface is clearly illustrated. Another fault has brought up a red sandstone, usually considered to be of Bunter age, containing many well-rounded sand-grains and signs of aeolian deposition. A little farther to the west a steeply-hading normal fault, a branch of the Eastern Boundary Fault, brings the Bunter Sandstone against Lower Wenlock Shales. From this point, until the main outcrop of the Old Red Sandstone is reached, the tectonics are obscure. Dr. Frank Raw explained his theory of Malvern tectonics, but exposures were not sufficient for members to be able to see how it could be applied in this area.

The party now made its way northwards, stopping at various exposures on the way, where the sequence is well exposed. In a quarry on Berrow Hill, Haffield Breccia is seen overlying nodular Wenlock Limestone and separated from it by a thin band of white clay. The Director interpreted the structure as a thrust fault, but a number of dissenting views were expressed and a stimulating discussion ensued.

Next Penny Hill Quarry was visited, by kind permission of Messrs. Coygen Quarries Ltd. Almost the full sequence of the Wenlock Limestone is here exposed, steeply-dipping and inverted. One bedding-plane is particularly notable for the inverted Stromatoporoids displayed. A typical Wenlock fauna was found.

In Woodbury Quarry, visited by kind permission of the owners, the party was able to see an almost complete succession from the Ludlovian into the base of the Downtonian. Once again, the dip is very steep and the beds are inverted. The Lower Ludlow beds are siltstones which weather easily. Here the Aymestry Limestone is noticeably silty, but the lime-content is distinctly higher than that in the Upper Ludlow beds. The Series yields many of the typical Ludlow brachiopods and corals. The Yellow Downtonian is found in one corner of the quarry, with the Ludlow Bone Bed at its base.

Tea was taken at Abberley, after which most members returned home, but a small party ascended Abberley Hill and was rewarded with an excellent view in all directions—the Wyre Forest; the Clent Hills; the Cotswolds and Breedon Hill; the Malverns and, in the distant south-west, the Black Mountains.

Field Meeting at Hereford

MIDLAND GROUP

7–9 May 1954

Report by J. D. LAWSON

Directors: B. B. Clarke and J. D. Lawson

Received 14 June 1954

THIRTY-NINE members attended the meeting, the administrative side of which was very efficiently organised by Mr. H. Sanders and Mr. E. D. Lacy. The headquarters were at the Kerry Arms Hotel, Hereford. An introductory talk was given by the Directors on the evening of Friday, 7 May.

Saturday, 8 May (Director: Rev. B. B. Clarke)

The first stop was made 3½ miles east of Hereford, at the long quarry (566.405) in the Bartestree dyke (Reynolds, 1908). This is a doleritic intrusion trending ENE.–WSW., i.e. at right angles to the main axis of the nearby Woolhope pericline. In the south-west face of the quarry the complete thickness (35 ft.) of the dyke is exposed, with the adjacent Downtonian marls altered to a hard grey rock containing yellow patches which simulate amygdales. Mr. Lacy described the characteristics of the rocks as seen in thin-section. From above the quarry the Director described the fine view of the northern and western dip-slopes of the Woolhope inlier and pointed out the small Silurian inlier, farther north, at Shucknall Hill. This inlier is bounded on its south side by an important fault trending ENE.–WSW., parallel to the Bartestree dyke, and lying in a direct line with the Neath disturbance. The party then drove to Shucknall to examine the succession in this interesting area which has never been fully described. The quarry at Shucknall Spout (588.427) yielded an abundant fauna including *Sphaerirhynchia* [*Wilsonia*] *wilsoni* (J. de C. Sowerby), *Dalmanella orbicularis* (J. de C. Sowerby), *Dayia navicula* (J. de C. Sowerby) and *Chonetes striatellus* (Dalman). There can be little doubt that these beds are equivalent in age to the Dayia Shales of the Shropshire area, but *Dayia navicula* itself is not usually as common in the main Woolhope area as it is at this locality, and Gardiner (1927) failed to distinguish this important horizon. Walking eastwards, the pathside-exposures showed a descending succession through Aymestry Limestone into the highest Lower Ludlow mudstones, crowded with small *Chonetes lepismus* (J. de C. Sowerby). Lower Ludlow strata have not been recognised previously, in the

Shucknall Hill inlier. Still further east, the Aymestry Limestone is well-exposed in a large quarry (592.431) showing the anticlinal crest and easterly-dipping bedding-planes. The abundant fauna included *Atrypa reticularis* (Linnaeus), *Leptaena rhomboidalis* (Wilckens), *Strophonella euglypha* (Hisinger), *S. funiculata* (McCoy), *Dalmanites vulgaris* (Salter), *Poleumita* cf. *globosa* (Schlotheim), *Favosites* sp., and simple corals.

On leaving Shucknall Hill there was an accidental split in the convoy of private cars. The main body of the party proceeded to the crossroads at the Trumpet Inn, to examine a roadside exposure in Downtonian red marls (657.397). After lunch, the missing members were discovered at Ledbury Station and the complete party was then taken to see the famous section in the cutting at the tunnel-entrance. This section in the Ledbury, or Passage Beds has been described by Symonds (1860) and Piper (1893), and the Director summarised their interpretations of the succession. The beds consist of sandstones and marls, predominantly red in colour. The sandstones yielded several small ostracoderm shields, fish spines and specimens of *Lingula cornea* (J. de C. Sowerby).

The next exposure at Frith Farm Quarry, north of Ledbury (717.398), provided highly-fossiliferous beds of Upper Ludlow age. The following fossils were found: *Chonetes striatellus*, *Dalmanella lunata* (J. de C. Sowerby), *Camarotoechia nucula* (J. de C. Sowerby), *Serpulites longissimus* J. de C. Sowerby, *Fuchsella* [*Orthonota*] *amygdalina* (J. de C. Sowerby), *Goniophora cymbaeformis* (J. de C. Sowerby), *Pteronitella* [*Pterinea*] *retroflexa*, *Michelinoceras* [*Orthoceras*] *bullatum* (J. de C. Sowerby), *Kionoceras angulatum* (Wahlenberg), *Cornulites serpularius* Schlotheim, *Calymene intermedia* Lindström. The final halt was made at an exposure of Lower Ludlow beds in a lane half a mile NE. of Ledbury Station (714.384), where numerous small brachiopods, such as *Dicoelosia* [*Bilobites*] *biloba* (Linnaeus) and *Cyrtia exporrecta* (Wahlenberg), were found. A vote of thanks to the Rev. B. B. Clarke was then proposed by Mr. Aiers, President of the Midland Group, for so kindly leading members on such an excellent excursion, and the party demonstrated their appreciation.

Sunday, 9 May (Director: Dr. J. D. Lawson)

Most of the exposures visited on this excursion have been described recently, in the Report on the Whitsun Field Meeting to Hereford in 1949 (Pocock, 1950). This traverse of the Woolhope inlier commenced on the western flank, at Prior's Frome (576.390), where the junction between the Grey Downtonian and Upper Ludlow was seen. Ascending the hill to Sufton Cockshoot (578.386), the party examined typical Aymestry Limestone, succeeded by shelly limestones, siltstones and shales which the Director considered, on faunal grounds, to be equivalent to the Dayia

Shales of the Ludlow area. Gardiner (1927) did not recognise this horizon at Woolhope and in the discussion on his paper it was suggested that the zone of *Monograptus leintwardinensis* might be absent in this area. The present Director, however, reported having found this graptolite, associated with *Sphaerirhynchia wilsoni* and *Dalmanella orbicularis*, in the beds above the Aymestry Limestone at Sufton Cockshoot.

The party then climbed over Lower Ludlow mudstones to Backbury Hill for the fine view of the inlier. After examining Wenlock Shales at Checkley Common (596.387), lunch was taken. In the quarries of Little Hill (613.381) the Wenlock Limestone yielded a large and typical fauna. The party next halted at Woolhope Cockshoot, to see the spectacular effects on the topography caused by dip-faulting. After examining the Ludlow Bone Bed horizon at Rushall (641.348), the eastern dip-slope was ascended to Sleaves Oak (630.347), where a fine view of the inlier was obtained. At Woolhope (613.357), the Woolhope Limestone was briefly examined, and the party then proceeded across the axial area of the pericline to see fossiliferous Upper Llandovery rocks at Haughwood's Cottage (587.365) and the Petalocrinus Limestone (Pocock, 1930) at Upper Littlehope (584.366). A last halt was made at the well-known Scutterdine Quarry (577.369) in the Woolhope Limestone. A group of well-rounded pebbles was discovered in the typical impure limestone. There was no sign of a continuous conglomeratic band and the largest pebble (a fine-grained greywacke) was about three inches in length, with its long axis vertical. The origin of these pebbles was the subject of some speculation, but no satisfactory explanation was given. Finally, the President, Mr. Aiers, proposed a vote to thanks to all those responsible for the direction and organisation of the excursion.

REFERENCES

Gardiner, C. I. 1927. The Silurian Rocks of Woolhope (Herefordshire). *Quart. Journ. Geol. Soc. Lond.*, **83**, 501–50.

Piper, G. H. 1884. The Passage Beds of the Old Red Sandstone at Ledbury. *Woolhope Trans.*, 136.

———. 1897. The Passage Beds at Ledbury. *Woolhope Trans.*, 310.

Pocock, R. W. 1930. The Petalocrinus Limestone Horizon at Woolhope, Herefordshire. *Quart. Journ. Geol. Soc. Lond.*, **86**, 50–62.

———. 1950. Report on Whitsun Field Meeting to Woolhope and May Hill. *Proc. Geol. Assoc.*, **61**, 202–5.

Reynolds, S. H. 1908. The Basic Intrusion of Bartestree, near Hereford. *Quart. Journ. Geol. Soc. Lond.*, **64**, 501–11.

Symonds, W. S. 1860. On the Passage-Beds from the Upper Silurian Rocks into the Lower Old Red Sandstone at Ledbury, Herefordshire. *Quart. Journ. Geol. Soc. Lond.*, **16**, 193–7.

Field Meeting at Highdown Hill, Clapham, and Storrington, West Sussex

Sunday, 23 May 1954

Report by the Director: E. C. MARTIN

Received 11 June 1954

DURING THIS Meeting a traverse was made from the Coastal Plain of West Sussex, across the Littlehampton Anticline and Chichester Syncline, and over the South Downs into the Weald. Beds ranging in age from the Basement Bed of the London Clay to the Folkestone Sands of the Lower Greensand were seen.

At Goring-by-Sea Station, where forty members and friends met at 11 a.m., the Director exhibited a cross-section of the country to be traversed, and pointed out that the Station lies a little north of the axis of the Littlehampton Anticline. This is a major tectonic feature responsible for a large inlier of Middle and Upper Chalk which underlies the 15-ft. Raised Beach, and other Pleistocene deposits of the Coastal Plain, for some seventeen miles west of Worthing (Martin, 1938). An area round the Station is mapped by H.M. Geological Survey as marine gravels, but no sections in these beds are now visible. All three pits seen by the Association at the Field Meeting in 1934 have been filled in. The Raised Beach at Goring rests on Middle Chalk, the whole of the Upper Chalk, 800 ft. in thickness, having been removed from this part of the Coastal Plain by marine erosion in Pleistocene times.

Leaving the Station the party followed the footpath along the north side of the railway, then turned northwards to the main road, crossing the Ferring Rife by a footbridge. This little stream rises on the Eocene Beds to the NE. of Highdown Hill and, in its brief course to the sea, crosses the Chichester Syncline and Littlehampton Anticline, without regard to the underlying geological structure.

Leaving the main road at North Barn, the party climbed the southern slope of Highdown Hill to Pit 31 (Gaster, 1924), which is due south of the clump of trees on the summit. This pit is in the *Uintacrinus* band of the *Marsupites* Zone and shows some 40 ft. of Chalk dipping northwards at about 30°. A collection of fossils from the pit was exhibited by the Director and a plate of *Uintacrinus* was found by one of the members.

The next halt was made on the western rampart of the Early Iron Age Camp which crowns the summit of the hill (269 ft. O.D.). From this point a good view was obtained of the level Coastal Plain and of the Downs to the north. The Director pointed out that the wooded valley separating Highdown Hill from the Downs marks the outcrop of the Eocene Beds which are preserved by the Chichester Syncline, while Highdown Hill is the surviving fragment of a former high range of Chalk downs which must have extended westwards from Worthing along the axis of the Littlehampton Anticline. The remainder of this range has been planed down to a level surface by marine erosion, the process being completed at the period of the 15-ft. Raised Beach.

The highest beds of Chalk exposed on Highdown Hill, in the Zone of *Actinocamax quadratus*, were seen in Pit 32, on the east side of the Camp, and the party left the hill by way of Pot Lane, passing immediately into the woods which mark the outcrop of the Eocene Beds. There are no adequate exposures of these on the south side of the syncline, but mottled red clay indicating the presence of the Reading Beds was noticed at the bottom of some old excavations to the right of the lane, a few yards down the hill. The outcrop of the London Clay was then traversed as far as Northdown Farm, from which a footpath led past the picturesque Patching Pond to the Horse and Groom Inn, where a halt was made for lunch. The pond is fed by springs thrown out at the junction between the Chalk and the Reading Beds.

After lunch a small section in the Basement Bed of the London Clay was examined on the west side of the footpath about 100 yds. south of the brickworks of the Clapham Common Brick and Tile Co. The Basement Bed at Clapham is a pebble-bed formed of a compact mass of well-rounded flint pebbles, mainly less than 1 in. in diameter. Its thickness is only 5–6 ft., but it is the local equivalent of the Blackheath Beds of the London District. The neighbouring brick-pit gives the best section in Sussex of the mottled red and bluish clays of the Reading Beds. Some sandier beds at the top, underlying the pebble-bed at the east end of the pit, contain ferruginous nodules from which the brachiopod *Discinisca ferroviae* Muir-Wood, and fish remains, have been obtained (Muir-Wood, 1939). Some of these nodules were broken by members of the party, but yielded only fragments of *Discinisca* and a tooth of *Odontaspis macrota* (Ag.) var. *striata* (Winkler).

Resuming the walk, the party followed a footpath northwards through the wood up the dip-slope of the pebble-bed and then crossed a small valley on the outcrop of the Reading Beds, to reach the village of Clapham, on the dip-slope of the Chalk. The next halt was in Pit 19 (Gaster, 1924), on the western edge of Church Copse, about 200 yds. west of Clapham Church. This pit shows a good section in the Zone of *Actinocamax quadratus* and shows well-bedded Chalk, with seams of flint-nodules at regular intervals, dipping gently southwards. From this pit the party crossed the valley and followed the bridle-path up Patching Hill and past Pit 21, which has been visited by the Association on two previous occasions (Martin, 1938, 1949). Until recently this pit was one of the most fossiliferous sections in the *quadratus* Zone which occurred in the district, but it has now been filled with chalk dug from a reservoir situated lower down the hill.

A short distance farther on a halt was made at a point from which a good view was obtained of the backs of the main and secondary escarpments. The latter consists of a line of separate hills, of which Harrow Hill, Blackpatch Hill and Church Hill, Findon, were visible from the view-point. Here the Director gave a brief account of the erosion-flats described by B. W. Sparks (1949). It was stated that the early Pliocene marine bench at 550–650 ft. O.D., which is a prominent feature of the North Downs and the Chilterns, is not much in evidence on the South Downs, but its presence was proved by the discovery of ferruginous sandstone, with marine Pliocene fossils, near Beachy Head (Edmunds, 1927). The summits of Harrow Hill (549 ft. O.D.) and Blackpatch Hill (553 ft. O.D.) have been regarded as relics of this surface. From the high sea-level of early Pliocene times the sea is believed to have fallen in stages, with halts of sufficient duration to cut flats at heights of 475, 430, 380, 345, 330, 290, 230 and 180 ft. O.D. The flats to the south of the secondary escarpment are believed by Mr. Sparks to be of marine origin, although no marine deposits have been found on them; those to the north of the secondary escarpment, on the other hand, are believed to be sub-aerial in origin. Several flats could be seen in profile from the point where the party was standing, the most notable being those on the NW. and SE. spurs of Blackpatch Hill (Nos. 27 and 28 of the 430-ft. series). Of these, the former is 1100 yds. long and ranges in height between 403 ft. and 428 ft. O.D., except for a small area which reaches 441 ft. O.D. The latter is 300 yds. long at 398–403 ft. O.D.

After listening to this account, the party traversed Flat 17 of the 330-ft. series. This particular flat is 400 yds. long, and has an almost level surface at 298–301 ft. O.D. It terminates at an overgrown chalk pit in the *quadratus* Zone, immediately inside Michelgrove Park, which has now been taken over by the Forestry Commission. A slight rise beyond the pit leads to Flat 18, which runs for 400 yds. at 315–330 ft. O.D., to the west of a ruined clock-tower. Mr. Sparks regards these two flats, separated by a break of slope, as evidence of the compound nature of the 330-ft. platform. After the position of the upper flat had been pointed out, the party then followed the footpath down to Michelgrove Farm, passing, on the left, an old quarry which gives a good section in the upper beds of the *Hagenowia* Horizon of the Zone of *Offaster pilula* (Gaster, 1937, 372).

Following the road to the north from Michelgrove Farm the party reached the south-east spur of Harrow Hill and, passing through a gate on the right, crossed Flat 19 of the 330-ft. series, halting at a low rectangular earthwork near the northern end of the flat. Mr. Sparks gives the elevation of the forward edge of this flat as 326 ft. O.D., while he considers the back is a gradual increase of slope towards higher ground. He sees in this flat evidence of a pronounced marine embayment at the 330-ft. stage (Sparks, fig. 37), but the Director expressed some doubt as to whether this flat was a true marine platform. Its profile, as seen from Patching Hill earlier in the afternoon, is distinctly dome-shaped, and it lies on the site of a Late Bronze Age farm, the fields of which, with their lynchets, once covered the whole area of the flat. The site is not marked on any of the Ordnance maps, but is well known to archaeologists under the name of New Barn Down. Its importance lies in its being a practically complete example of a Late Bronze Age agricultural settlement, unobscured by any later prehistoric occupation (Curwen, 1934).

Leaving the earthwork which once surrounded the farmyard and huts of this old settlement, the party followed the bridle-path over the south-west spur of Harrow Hill. Looking back, the double-lynchet road which led to the Bronze Age farm was a striking feature in the field below New Barn Down, and the down itself presents a much more horizontal profile when viewed from this direction. Looking westwards, two more flats were seen in profile on Barpham Hill. The higher of these, No. 22 of the 475-ft. series, truncates the top of the hill for 400 yards at 469–459 ft. O.D. If this is indeed a marine platform, then this part of the secondary escarpment must have been completely submerged at the 475-ft. stage. The lower flat, No. 24 of the 430-ft. series, extends for 700 yards at 425–404 ft. O.D.

On the descent towards Lee Farm some outcrops of the *Marsupites* band were seen in the banks of the bridle-path. From these a plate of *Marsupites*, and a specimen of *Echinocorys scutatus* var. *elevata*, Brydone, were obtained by members. Passing an old chalk pit in the *Uintacrinus* band on the side of Harrow Hill opposite Lee Farm, the party began the long but gradual ascent to the main escarpment. A brief halt was made on Flat 23 of the 475-ft. series. This flat is not very clearly defined. Mr. Sparks gives the elevation of its forward edge as 477 ft. O.D., and states that the back cannot be fixed, as the spur flattens gradually. It makes, however, one of the finest view-points for the line of hills forming the secondary escarpment, and in the opposite direction, across the valley to the west, it gives a good view of an impressive group of lynchets belonging to the Celtic Field System. The Director expressed the view that this ancient cultivation, which in some areas was continuous from the Late Bronze Age down to Romano-British times (a period of at least 1000 years), must have had some modifying effect on the surface-features of the Downs and should be taken into account in considering the subject of flats.

The main escarpment was reached at Chantry Post (626 ft. O.D.), from which a good view of the Weald was obtained. The party followed the road down the east side of a fine semi-circular coombe, which bites deeply into the escarpment at this point. A short distance below the summit an old quarry by the roadside yielded a few fossils indicating the *Holaster planus* Zone. Near the bottom of the hill the road passes another old quarry in the *Holaster subglobosus* Zone, while above it, just below the fence at about 400 ft. O.D., an outcrop of the Melbourn Rock, at the base of the Middle Chalk, was pointed out.

The party left the Downs at The Chantry house, passing, on the right, a very picturesque pond which is fed by springs thrown out by the marl beds at the base of the Chalk. This pond is the source of the little River Stor which flows down by the roadside to a small waterfall, opposite which a brief halt was made to examine a section of the malmstone band of the Upper Greensand which is exposed in the road bank. A short distance below the waterfall the stream leaves the roadside and passes onto the Gault, which can be seen in the banks of the stream just beyond the point where the stream leaves the road. The road was followed past Chantry Mill to the large pit of the Marley Tile Co. This pit has altered considerably since it was last visited by the Association (Bull and Kirkaldy, 1947) and is now in a somewhat unsafe condition, due to some recent and rather spectacular land-slipping to the east of it, but it still shows a fine section in the Folkestone Sands and the Gault, capped by the white flint drift of the 200-ft. platform. The main feature of the section is the remarkable bed of pebbly limonitic grit which forms the basal bed of the Gault in this part of Sussex. This bed has been described by Dr. J. F. Kirkaldy, who sees in it some evidence that the growth of the Wealden dome may have commenced in Albian times (Kirkaldy, 1935).

A short walk across the fields brought the party to Storrington for tea at the Manor House Hotel, where the President, Dr. L. R. Cox, proposed a vote of thanks to the Director, after which the party walked to the Storrington Bus Station for a bus into Worthing.

REFERENCES

Bull, A. J. & J. F. Kirkaldy. 1947. Whitsun Field Meeting to the Central Weald; Storrington to Petworth. *Proc. Geol. Assoc.*, **58,** 80.

Curwen, E. C. 1934. A Late Bronze Age farm on New Barn Down, Clapham, near Worthing. *Sussex Archaeological Collections*, **75,** 137–70.

Edmunds, F. H. 1927. Pliocene Deposits on the South Downs. *Geol. Mag.*, **64,** 287.

Gaster, C. T. A. 1924. The Chalk of the Worthing District. *Proc. Geol. Assoc.*, **35,** 89–110.

————. 1937. The Stratigraphy of the Chalk of Sussex. Part I. West Central area, with Zonal map. *Proc. Geol. Assoc.*, **48,** 356–73.

Kirkaldy, J. F. 1935. The Base of the Gault in Sussex. *Quart. Journ. Geol. Soc. Lond.*, **91,** 519–37.

Martin, E. C. 1934. Field Meeting at Highdown Hill and Angmering-on-Sea, West Sussex. *Proc. Geol. Assoc.*, **45**, 427–31.

———. 1938. The Littlehampton and Portsdown Chalk Inliers and their relation to the Raised Beaches of West Sussex. *Proc. Geol. Assoc.*, **49**, 198–212.

———. 1939. Field Meeting at Highdown Hill, Clapham, and Angmering, West Sussex. *Proc. Geol. Assoc.*, **50**, 72–6.

———. 1949. Field Meeting in the Worthing District. *Proc. Geol. Assoc.*, **60**, 44–7.

Muir-Wood, H. M. 1939. Four species of *Disciniscа* (Brachiopoda) from the Eocene of the Hampshire Basin. *Proc. Geol. Assoc.*, **50**, 149–58.

Sparks, B. W. 1949. The Denudation Chronology of the Dip-Slope of the South Downs. *Proc. Geol. Assoc.*, **60**, 165–215.

Field Meeting in Sheppey

11 July 1954

Report by the Directors: A. G. DAVIS and G. F. ELLIOTT

with a

Note on the varying condition of the Sheppey Cliffs and Foreshore

by G. F. ELLIOTT

Received 16 July 1954

TWENTY MEMBERS and friends assembled at Charing Cross and proceeded to Sheppey by motor-coach. A route-diversion afforded an unexpected sight of various road-side sections and scenery in the Doddington–Newnham Valley. Three joined the party in Sheppey, where lunch was taken on Warden Cliff, after which one of the directors (G.F.E.) gave a brief account of the geology, and history of palaeontological investigation, of the London Clay on the island. Descending to the beach, the party welcomed two enterprising members who had travelled by motor-launch from the opposite Essex coast and landed at Warden by dinghy. After collecting here, the party proceeded westwards, examining cliffs and foreshore. At Barrow Brook the anomalous bedding noted on a previous excursion (June 1951) was demonstrated; from the orientation of septaria, and other indications, the bedding was seen to be vertical in the cliff and foreshore, and Mr. D. Curry traced this feature some distance inland, along the ravine occupied by the Brook. The clay at this point is the undisturbed division *b* of Davis (*Proc. Geol. Assoc.*, **47**, 330), and it is possible that this bedding initiated the drainage now represented by the little Barrow Brook. When further collecting had been carried out, westwards, the party ascended the ravine at Barrow Brook and returned by the cliff-path to Warden, where tea was taken in the garden of the Post Office. A group of specimens representative of the fossil flora and fauna was obtained by the party, including some choice fruits, a fine sprig of a conifer, and the cephalopod *Belosepia*. Minerals found included a good specimen of chalcopyrite.

A vote of thanks to the Directors, and to the Excursion Secretary, Miss H. Wilkinson, was proposed by Mr. D. Curry, after which the main party returned to London.

Note on the varying condition of the Sheppey Cliffs and Foreshore

by G. F. ELLIOTT

THE DISAPPOINTING result often obtained by the fossil-collector at classic localities, even when the latter are permanent natural coast-sections, is well known. The present note discusses this phenomenon for the London Clay of Sheppey, and is based on the notes of Mr. A. G. Davis from the 1920s onwards, and upon those of the writer from 1937.

Over the last twenty years conditions may be summarised as follows: 1934–5, good; 1936, poor; 1937–8, good; 1939, poor; 1940–5, no record; 1946–7, poor; 1948, good; 1949–53, poor; 1954, good. The successful collection of fossils *in situ* depends upon not only the sliding of large, undistorted masses of fossiliferous London Clay to beach-level, but also upon being able to distinguish bedding in these masses. Most of the Sheppey fossils have been obtained from beach material, particularly pyrites and septaria, washed free by the tides. Periods of wet weather give rise to slumped and jumbled masses of clay, and to extensive mudflows from shelves or undercliffs. These result in a confused cliff, and a very muddy beach, both of which conditions persist for a long time. On the other hand, dry weather, or frost, results in extensive cracking of the clay, when the tumbled fragments are cleared relatively quickly by the tides, and the detritus and fossils freshly exposed on the foreshore.

It will be seen that under normal weather conditions the good years are exceptional.

My thanks are due to Mr. Davis, and various other workers, with whom I have discussed this problem.

The Geology of the Lake District—a review

by S. E. HOLLINGWORTH

with contributions by W. C. C. Rose, R. L. Oliver and
R. J. Firman

Received 11 June 1954

CONTENTS

1. INTRODUCTION ... ... *page* 385
2. SUMMARY OF GEOLOGICAL HISTORY 386
3. A REVIEW OF PROGRESS IN RESEARCH 389
   (a) Skiddaw Slates 389
   (b) Skiddaw Slates–Borrowdale Volcanic Series Relationships 391
   (c) Borrowdale Volcanic Series 392
   (d) Structure 396
4. CONCLUSIONS 400
   REFERENCES 400
   EXPLANATION OF FIGURE 402

SUMMARY: The paper includes a brief geological history of the Lake District as a whole, followed by a review of the progress and present state of research in the many problems provided by the Lower Palaeozoic rocks. This review is mainly concerned with advances made since the publication in 1916 of Marr's *Geology of the Lake District.*

---

1. INTRODUCTION

CONSIDERING THE INTEREST, and variety, of the geology exhibited by the English Lake District, it has not been visited frequently by the Geologists' Association. During this century, apart from the West Cumberland meeting based on Whitehaven in 1924, the central part of the district has only been visited by the Association once, with J. F. N. Green as Director in August 1920. At that time the Association's leader had completed several years' study of the volcanic rocks, intrusions and structure of the district. Many of his stimulating and somewhat unorthodox ideas had been put forward in a series of papers published in the PROCEEDINGS and in two Presidential Addresses (1915, 1921). Much detailed work has been carried out on a great variety of aspects of the geology of the district since these field meetings and a large proportion of this research has been published in the PROCEEDINGS. It would be difficult in a few pages to combine an attempt to give a general account of the geology of the district with adequate attention to the work carried out in the last thirty years, and the reader is, therefore, referred to *Geology of the Lake District* (Marr,

1916) and to the *Regional Geology: Northern England* (Eastwood, 1946). It has been suggested, however, that a brief review of the present position of geological research in the region would be helpful to members attending the Field Meeting and to others visiting the district. This will be preceded by a summary of the geological history of the district.

It is well to recall that the occurrence in the central mountainous core of two great slaty sedimentary groups of pre-Carboniferous strata separated by volcanic rocks and traceable in upward succession southward from the Skiddaw area was first established by Jonathan Otley. Individual investigations by Sedgwick, Harkness, Nicholson and others prior to the six-inch mapping of the area by the Geological Survey built a sound foundation of basic knowledge of the geology and palaeontology of the Lower Palaeozoic strata. The six-inch survey carried out during the period 1860–90 by Ward, Aveline, Daykns, Goodchild and others was followed by the publication of engraved six-inch geological sheets. This survey formed the basis of the Old Series, hand-coloured, one-inch geological maps on a contourless, but hachured, topography. These maps are still the only official one-inch maps available for this much visited region.

Much detailed research has been carried out since the completion of this survey and the publication of the memoirs dealing with parts of the area. Later progress in our knowledge may be divided into two periods: the first included study of fossiliferous strata concerning which Marr's name will always be outstanding, and study of igneous (mainly intrusive) rocks in which Cambridge Geologists led by Harker were predominant. This period may be said to have ended with the publication of Marr's classic work on *The Geology of the Lake District* in 1916, in which geomorphological studies received particular attention. The second period has been concerned very largely with the investigation and the detailed re-mapping of the Borrowdale Volcanic Series. Work on the western and northern marginal areas of the Lower Palaeozoic inlier has also been carried out in so far as those areas formed part of the one-inch maps under revision by the Geological Survey.

2. SUMMARY OF GEOLOGICAL HISTORY

Ordovician. The earliest known sediments are marine grits and flags belonging to Skiddaw Slates. These have received the local names of Loweswater Flags and Watch Hill Grits. They are followed by a bluish-grey, arenaceous–argillaceous, striped group (Mosser Slates) and these appear to pass upwards into a group of dominantly black, more argillaceous slates (Kirkstile Slates). The formation, probably several thousand feet thick, represents the Arenig and part of the Lower Llanvirn. Reversion to an arenaceous facies, the Latterbarrow Sandstone, occurs locally in the west having been deposited immediately before the onset of volcanic activity.

The Borrowdale Volcanic Series (Green Slates and Porphyry of Sedgwick) follow conformably. They consist of lavas, tuffs and conglomerates in great variety. Several thousand feet are present, except in the south-west, where the succession appears to be greatly attenuated. It may also be comparatively thin in the south-east. It is probable that this volcanic episode spanned Upper Llanvirn and part of Llandeilo times.

After an interval of gentle folding about north-north-east axes, which are recognisable principally in the southern part of the District, there was considerable denudation with local cutting out of the whole of the Borrowdale sequence in the south-west at Greenscoe (Smith, 1924 *with references to earlier work*) before deposition was resumed in the form of coarse detritus derived from the volcanic rocks. This initiated another marine episode of limestones and shales of the Coniston Limestone and Ashgillian Series. Rhyolitic lavas and beds of ash were locally developed at this time.

Silurian. The Stockdale Shales follow conformably. They comprise highly-fossiliferous dark shales (Skelgill Beds) followed by the purplish-red and grey Browgill Beds. Conditions were those of slow, quiet deposition and the beds are equivalent to several thousand feet of Llandovery strata in the Welsh Borderland. More rapid sedimentation of Brathay Flags, Lower and Upper Coldwell Beds, Coniston Grits, Bannisdale Slates and Kirkby Moor Flags, in all some 12–13,000 ft. of strata, represent the Wenlock and Ludlow Series.

Caledonian Orogeny. Representatives of the Downtonian are absent and it is probable that the great Caledonian mountain-building movements were initiated at this time and continued into the Devonian period. Intense folding and cleavage of the rocks, together with substantial faulting, took place. These movements were associated with, and followed by, the emplacement of granite and basic igneous masses as well as numerous dykes.

Great erosion followed the elevation of this part of the Caledonian Mountain chain. It is clear that this erosion had reached an advanced stage when the Mell Fell Conglomerate, of pre-Upper Old Red Sandstone age, was formed. These conglomerates were derived largely from the Silurian strata, but were laid down on an uneven surface of Skiddaw Slates and Borrowdale Volcanic Series. J. G. Capewell (1954) has recently shown that they suffered warping and considerable erosion before the uppermost beds of conglomerate, which preceded the deposition of the Carboniferous marine sediments, were laid down.

The main structures found within the Palaeozoic core of the limestone were produced during this orogenic period, as is evident from the relatively gentle disturbance of the Carboniferous Limestone, where this is preserved dipping outwards from the Lower Palaeozoic core.

Carboniferous. The Upper Palaeozoic and Mesozoic rocks surrounding the Palaeozoic core are much faulted. These movements are partly post-Carboniferous and pre-Triassic, and partly post-Triassic. It is probable that, during both of these periods of faulting and tilting of the strata, similar movements extended into the compacted rocks of the core. Such fractures are the sites of contemporaneous or later mineralisation and have had an important influence on the detail of the river pattern.

The unconformable base of the Permo-Triassic breccias and sandstones transgresses from the Coal Measures across the Carboniferous Limestone on to the Borrowdale Volcanic Series. This indicates the magnitude of the break and the amount of erosion, which took place in the interval corresponding to the main Hercynian orogeny of southern Britain.

Mesozoic–Tertiary Period. It is probable that the whole district was eventually covered by the Keuper Marl deposits at the end of Triassic times, although there is no definite evidence for this view. Liassic strata are preserved in the axial region of the Carlisle or Solway Basin to the north and it is possible that these Jurassic strata also covered the area. Considerable movements in Upper Jurassic–Lower Cretaceous times are more than a possibility in view of (a) the presence of major crustal movements of that date in the Inner Hebrides and elsewhere, and (b) general geomorphological considerations, in particular the river-pattern, which would suggest superimposition of the latter from a cover of newer sediments. If such a cover existed at the time of the initiation of the present drainage pattern, it presumably rested unconformably in turn across the denuded edges of Jurassic, Triassic, Carboniferous and Lower Palaeozoic rocks in passing from the outer part of the Lake District dome towards the centre. An Upper Cretaceous age for the cover would seem to be a reasonable possibility. The alternative would be to regard the present domed surface as a warped, early Tertiary peneplain.

Geomorphological studies by a number of workers (Hollingworth, 1937; McConnell, 1939; Miller, A. A., 1939) have shown the presence of erosional benches which indicate that the present elevation of the area was attained by a series of intermittent but uniform uplifts which were, in general, later than the actual doming of the present surface. The greater part of this uplift preceded the oncoming of glaciation, the effects of which are so strongly imprinted on the topography of the area. The valley-system has been subject to many piratical adjustments, spread over the long period of pre-glacial denudation. Some of the modifications appear to be directly related to individual rejuvenations of the rivers due to the intermittent Tertiary uplifts.

Pleistocene. Broadly speaking, the effects of glaciation are erosional in the area of Lower Palaeozoic strata. They reached their greatest intensity in those preglacial valleys which were most favourably situated for the accumulation and rapid movement of the ice, of which the Ullswater and Haweswater valleys are perhaps the most striking. In other parts, such as the extreme south-east adjoining the Howgill Fells and the valleys north of the Skiddaw–Saddleback Ridge, glacial erosion is less pronounced, and much of the preglacial surface has been but little modified. The least modified topography is that of the higher watersheds such as the High Street and the Helvellyn Range, where the smooth rounded surface is part of a mature topography which dates from before the late-Tertiary regional elevations and their consequential rejuvenation effects in the valleys. Intermediate in position and altitude between this preglacial upland and the glacially modified rejuvenated valleys and valley-heads are extensive areas of rugged topography, over which ice was thick enough for ice-plucking action to be quite powerful. Here the actual lowering of level of the preglacial surface is probably not great compared with that in the overdeepened valleys.

There is in the outer fringe and in the lower portions of the valleys a good deal of boulder clay produced by sub-glacial deposition. In general the amount of frontal morainic material attributable to a valley-glacier stage in the recession of the ice is very small. It is in accordance with the evidence outside the mountain district itself that the final disappearance of the last confluent ice-sheets from the area took place at a time when the snow-line had already risen above the mountain tops. The dying ice melted away in the valley with little active feed from the valley-heads. An excellent example of a kettle-holed terrace at 150 ft. O.D. formed marginal to dead ice on the west side of Windermere may be cited as belonging to this phase. Moraines, which are plentiful in the recesses of the hills, are, in all probability, due to a recrudescence of glaciation of a modest and brief character such as was suggested many years ago by Marr (1916, p. 196).

Recent studies of the post-glacial flora in Britain of recent years have resulted in the recognition of the presence of a climatic deterioration in post-glacial times that can with confidence be correlated with the Allerød oscillation of Denmark and Scandinavia. The recognition of a temperate diatomaceous layer between two deposits of laminated clays in the bottom deposits of Windermere (Pennington, 1947) appears to fit in with this oscillation. The upper series of laminated clays followed a phase of mild climate and is considered to indicate seasonal deposition on the lake-floor such as would be consistent with a seasonal variation in sediment brought down by the streams and a winter freezing of the lake. Large snowbanks and cirque glaciers in the recesses in the hills may have been adequate sources for these lake-sediments. Much of the scree-formation and the large alluvial delta-fans into the lakes also date from this period.

3. A REVIEW OF PROGRESS IN RESEARCH

(a) **Skiddaw Slates.** During the primary six-inch survey, the Skiddaw

Slates proved to be an intractable group, which was difficult to map, and no clear succession was established.

During the survey of the Whitehaven Sheet (1-inch 28), E. E. L. Dixon recognised and mapped a number of distinctive lithological types and put forward a succession (1925, pp. 70–1) which he subsequently modified (*in* Eastwood *et al.*, 1931, pp. 34–5). The re-survey of the Cockermouth Sheet (1-inch 23, 1928–32) included much of Skiddaw itself and the country lying to the east and west. Here a sequence of grits and flags, followed by striped and black slates, was recognised by survey officers (Trotter, Hollingworth, Eastwood, Rose) as applicable throughout the area surveyed; and W. C. C. Rose, who has mapped a large area lying to the west of the Bassenthwaite–Derwent Valley and in the angle between the Cockermouth and Whitehaven Sheets, finds that a similar succession holds there.

A feature of particular interest is the origin of the rock-type termed Blakefell Mudstone by E. E. L. Dixon. It is a pale grey siltstone or silty mudstone with minute spotting. Where originally studied it was remote from any major intrusion (Eastwood *et al.*, 1931, p. 25 and pp. 38–9), but rocks resembling it occur adjacent to the Ennerdale Granophyre (*op. cit.*, pp. 40–1) and have since been mapped over a wide area by Rose. Similar pale grey rocks are found in the Cockermouth Sheet adjacent to basic minor intrusives and also where the silty Skiddaw Slates are in contact with the Carrock Fell Gabbro. Indications of soda-metasomatism are present in these occurrences and similar metasomatism had been suspected in the rocks near the Ennerdale Granophyre.

Dixon also described chiastolite slate and tourmaline-bearing hornfelses remote from any visible intrusion. A possible extension of either the Skiddaw Granite, or the Eskdale Granite, has been suggested by Dixon to account for these metamorphosed rocks, and Rose also shares this view for the occurrences west of the Bassenthwaite Valley (see p. 394, Fig. 1 below).

The Watch Hill Grits, which form a series of detached outcrops within the slate-belt on the northern side of the main anticlinorium, were considered by Ward (1876) to be high in the slate succession. J. F. N. Green gave a new interpretation in making them a series of synclinal infolds of a basal Bala Grit resting unconformably on the Skiddaw Slates. In the Whitehaven Memoir, Ward's view of the position of these beds was revived with Green's concurrence. In the re-survey of the Cockermouth Sheet the equivalence of these grits to the other grits, recognised by Ward as being low down in the sequence (within the Loweswater Flags of Dixon), was firmly established.

While the general sequence appears to be well established, there is some evidence for variations in the lithology, particularly the reduction in the grits in a southerly direction, and the zonal succession remains somewhat uncertain.

The recognition of the faunal succession is handicapped by the absence of any recorded faunas from large tracts of country and by the fact that most of the collecting has been done from scree material. Much pioneer work had been done by Postlethwaite, Nicholson and Marr. Dixon (Eastwood *et al.*, 1931, pp. 31–6) has maintained that the succession of faunal assemblages more closely resembles that of the Lévis Shales of Quebec than that of Wales, but Dr. Elles (1933) did not accept this interpretation and considered that the Welsh zonal succession of the Arenig and Lower Llanvirn with a four-fold division of the *extensus* Zone can be recognised. It was not found possible to apply this detailed zonal scheme during the mapping of the slates in the Cockermouth Sheet.

Areas not yet examined in detail include the southern side of the Skiddaw –Saddleback mass, the detailed structure of which would well repay study; and the slates of the Black Combe Inlier in the extreme south-west of which little is known beyond the primary division into two main lithological types, made by Bernard Smith (1912, p. 404, fig. 1).

(b) **Skiddaw Slates–Borrowdale Volcanic Series Relationships.** It is generally accepted that the Borrowdale Volcanic Series succeed the Skiddaw Slates without any considerable discordance or stratigraphical break. Harkness (1863) recorded the actual junctions as normal contacts; but the primary geological survey interpreted these junctions as a series of high-angle faults of varying trend. Marr considered the junction to be a low-angle tectonic one, in which the movement was of the 'lag fault' type. Green criticised the latter view and claimed that the actual junctions were almost everywhere conformable and without tectonic disturbance.

In his work on the Volcanic Series of the eastern part of the Lake District, G. H. Mitchell (1934) found that the junction was so much obscured by drift as to make the relations of the two formations uncertain. On the northern boundary, passage by alternation was established by Dr. Trotter (1944) in the Overwater area, but farther east overthrusting of Skiddaw Slates on to the Borrowdales is clearly demonstrable, e.g. on Great Scafell (Hollingworth, 1938, fig. 1). Green claimed a normal junction along the line between Buttermere and Ullswater, but it seems probable that along much of this belt there was substantial movement between the two rock-groups, possibly in part along low-angle planes. It is indeed difficult to envisage the intense crumpling of the Skiddaw Slates developing beneath the thick, massive and competent cover of gently folded volcanics to the south without some considerable adjustment, which might well take place within the Skiddaw Slates. It seems inevitable that the folding of these two groups would in large measure be disharmonic[1], and the actual overturning of a great thickness of Borrowdales on the northern outcrop is an indication of the intensity of the compression which, incidentally, found relief there by strong overthrusting in a northerly direction. A northward movement of the whole of the slate-core of the overturned anticline relative to its envelope of volcanic rocks is consistent with Marr's conception (1916, p. 177) of low-angle lag-planes associated with the junction on the south side of the anticline. As the location of the main belt of differential movement may well be within the Skiddaw Slates, it is not difficult to reconcile this view with Green's evidence of normal actual contacts of the base of the Volcanics with the Skiddaw Slates. Indeed, the complicated structures found by Rose *within* the Skiddaw Slates and beneath the Borrowdales west of Bassenthwaite are regarded as related to such movement.

---

[1] Ward (1876, p. 68) wrote: 'This intense lateral pressure, while producing cleavage both in the Skiddaw Slates and Volcanic Series, affected the two formations differently as regards contortion; in one case it crumpled the beds, except where much banded by sandstone, with others it threw them merely into a series of low curves'.

(c) Borrowdale Volcanic Series. On account of the excellence of exposures, the variety of rock-types and the frequent repetition of the succession by folding, this formation presents an excellent opportunity for the study of many aspects of volcanic phenomena within a thick series of lava-flows and fragmental rocks. During the primary Six Inch Survey, Ward (1876) mapped many lithological junctions between lavas and ashes or tuffs and recognised some of the major structures. He also recorded in detail the succession of lavas at a number of localities, particularly Falcon Crag, near Keswick, and on Eycott Hill, in the extreme north-east, and was one of the pioneers in the microscopic examination of such rocks. He did not, however, fully appreciate the importance and extent of the flow-brecciation produced during movement of fluid lavas, and much material of such origin was recorded as ash and lava of explosive origin. Although Marr (1900, p. 469) in common with Ward recognised the presence of flow-brecciation, its full significance was not appreciated until much later. Marr and Harker had in 1900 attempted a major sub-division of the Borrowdale Volcanic Series and had shown the distribution of these divisions on a small-scale provisional map, together with a section across the central part of the Lake District. In the latter, the major structural features, such as the broad syncline through Scafell (recently re-surveyed by R. L. Oliver) and the Langdale Anticline, which was later mapped in detail by Hartley, were clearly illustrated.

The use of flow-breccias in the interpretation of the rocks and the revision of Ward's maps on this basis was largely pioneered by Green, who, after some misreading of auto-injected andesites as intrusive phenomena in his early Millom paper, became the first to appreciate fully the great extent and thickness of the flow-breccias. His Presidential Address on the vulcanicity of the District is a penetrating contribution to a complex and many-sided problem. Green (1911) established a volcanic succession between Skiddaw Slates and Coniston Limestone in the Millom area and, in 1915, he applied this succession of lava- and tuff-groups to the eastern part of the Lake District. He stressed the importance of low sheet dip in a region of complex folding of no great amplitude and, on the basis of the presumed persistence of rhyolite as indicative of a high horizon in the sequence when followed northward from the 'Upper Rhyolite' of Marr in the south, inferred from its outcrops the position of synclinal infolds. Green's work no doubt stimulated a renewed attack on the volcanic rocks. Hartley (1925, 1932, 1941) and Mitchell (1929, 1934, 1940) gradually through the years re-surveyed large areas of the mountain country (see p. 394, Fig. 1). In the south-east Mitchell's detailed mapping differed substantially from that of Green where their areas overlapped. In particular he found that rhyolites came in at more than one horizon in the middle and the lower parts of the succession, so modifying Green's structures considerably. His mapping indicated substantial changes in Green's views of the position of the major folds and in the inclination of their axial planes. This re-interpretation of the Manchester Corporation's five-mile-long tunnel from Haweswater to Long Sleddale (Mitchell, 1934, p. 442, and pl. XIV) was confirmed in the examination by Mitchell and myself.

Meanwhile, the Geological Survey had been mapping those areas of the Lower Palaeozoic rocks that are included in the maps which cover the coal and iron ore-bearing areas of West Cumberland. In this work, the lower parts of the valleys of Eskdale, Wasdale, Ennerdale and Loweswater were surveyed and the work was continued round the northern side of the Lower Palaeozoic area from Bassenthwaite to Eycott Hill. The positions of the areas re-surveyed are indicated on Fig. 1. In the Gosforth Sheet the synclinal area of rhyolite rocks, apparently the south-westerly continuation of the Scafell Syncline, was identified between flanking areas of andesites. It was suggested that the field-relations and the disturbance of the Latterbarrow Sandstone and Mottled Tuffs at the base of the Volcanic Series could be regarded as being a consequence of a complex major structural disturbance of low angle character at the junction of the Skiddaw Slates and Volcanic Series.

In the area covered by the Cockermuoth Sheet, F. M. Trotter and the writer were able to link up the well exposed sequences of lavas and tuffs of Binsey and Eycott Hill (for sections see Eastwood, 1946, p. 16, fig. 6). It is clear that a much greater thickness of volcanic rocks, probably 10,000 ft. in all, is present in the Binsey area. This succession includes a lower, tuff-rich group not represented farther east on Eycott Hill. It is of interest to recall in this connection the views of Marr, that, in passing from Eycott Hill westward towards the Keswick area on the main outcrop, the Falcon Crag group comes on in a westerly direction beneath the basic lavas of Eycott Hill.

Study of the main mass of the Borrowdale Volcanic Series, forming the central part of the Lake District and the southern flank of the Skiddaw

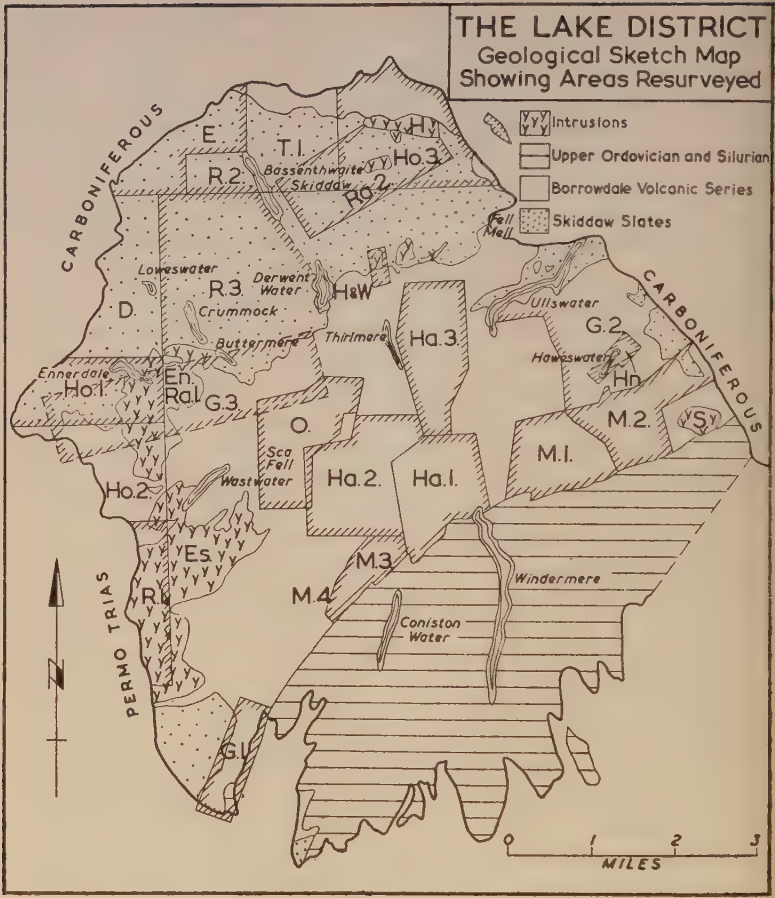


Fig. 1. Map of the Lake District showing areas re-surveyed. (For Explanation see p. 402)

Anticline, has been greatly facilitated by the fact that lavas and tuffs alternately dominate the succession and so form natural groups. The mapping of these has provided the key to the unravelling of the structure. There are numerous minor tuff-bands within the major lava-groups, and individual flows within the thick tuff-groups are by no means uncommon. Fig. 1 shows the extent of the area mapped on this basis. It suggests that the time is approaching when an effort should be made to fill in the gaps of the distribution-picture that is at present available, and so to link up the local successions.[1] It should be possible to develop a picture which would give the clues to the dying out of some groups (as suggested by Marr) and to indicate the overlapping of deposits from various centres outside the exposed area, as has, for example, been envisaged by Green (1919, p. 171) and by Mitchell (1929, p. 42). Such a picture would be essentially a broad impression. The area would still possess material for many years field-work and laboratory research. For example, individual flows can be mapped: as indeed Ward found in places during the original geological survey, and the interdigitation of petrographically contrasting deposits can in consequence be studied in detail as the writer found in the revision of Eycott Hill.

The first attempt at a stratigraphical succession of the volcanic rocks was made by Harker and Marr in 1900. It had a distinct petrographic basis. Now the general succession of lithological groups has been established for most of the area and much petrographic data has been accumulated. It seems that more intensive studies in the future will involve the mapping of individual lavas wherever practicable and probably their classification into 'types' according to petrographic and chemical characters. Conclusions of regional application may well appear from such studies. One may refer to the tendency, noted by Hartley (1941, p. 137), for the enstatite-bearing andesites to be restricted to the lower part of the succession. On the other hand, rhyolites, formerly regarded as restricted to near the top, have been found quite low down, particularly in the Haweswater area (Mitchell, 1934).

Much remains to be learnt concerning the conditions of accumulation. Green considered the series as a whole, both lavas and tuffs, to be of dominantly submarine deposit. Mitchell has considered some of the tuffs to be subaerial; for example, in his lowest division, the Nan Bield Andesites, and in the Wrengill Andesites in the middle of the succession; but regarded the Middle Tuffs (= Bedded Tuffs) as of fairly deep-water accumulation. Well-rounded cobbles in some coarse tuffs suggest derivation from land areas. R. L. Oliver infers a subaerial origin for lavas in his Grey Knotts division from the frequent occurrence of reddened tops. It may well be that his interpretation of much of the fragmental material as welded tuff (see p. 407 below) may also favour subaerial conditions of deposition. The complete absence of material of recognisably non-volcanic origin from the main mass of the formation is noteworthy and is in striking contrast to the interbedding of volcanic and non-volcanic sediments of the same general age in the Cross Fell area.

The secondary alteration of both lavas and tuffs has been the subject of much discussion. Intense epidotisation, which is a feature of the rocks adjacent to the Eskdale and Ennerdale intrusions, is by no means confined to those localities. Silicification associated with the development of pyrite is strongly developed locally, for example, in the ground north-west of Wastwater (Hollingworth *in* Trotter *et al.*, 1937, pp. 30–7). This process in forming the 'felstone-like ash' of Ward and hornstone of Oliver is widespread in the finer-grained tuffs of the central fells, but, for reasons not fully understood, it is by no means general. Hartley found the distribution of certain types of altered tuffs—notably concretionary structures in fine-grained tuffs—determined by proximity to the Langdale Rhyolites, which he considered to be emplaced by an intrusive mechanism under a shallow cover. The distribution of garnet and its associations, not only in lavas and tuffs, but also in a variety of minor intrusions, is a difficult problem that was investigated by Walker (1904) and at a later date by Green (1915*b*). The majority opinion appears to favour a secondary or hydrothermal origin; but the support for a magmatic origin is not lacking. The whole field of secondary alteration demands both more precise, and broader based, studies. The contribution by R. J. Firman (p. 412 below) may be referred to in this connection.

---

[1] It has not been considered advisable to attempt a correlation chart here.

(d) **Structure.** The north-north-easterly trending pre-Bala folds (Aveline, 1888, p. 8; Green, 1915), mapped in detail by Mitchell and Hartley, are best established in the southern areas where the folds, appearing from beneath the unconformable base of Bala rocks, have been traced northwards by means of the culminations and depressions in the crests of the east-north-east–west-south-west Caledonian folds. Bernard Smith (*in* Eastwood *et al.*, 1931, p. 29) recognised two sets of folds in the Skiddaw Slates in the extreme west, but it is not known whether these represent distinct periods of folding.

Neither the pre-Bala folding nor the unconformity associated with it can be followed across the full width of the outcrop of the Volcanic Series. In the north-east, however, two facts—the presence of the outlier of Upper Ordovician Drygill Shales north of Carrock Fell and the dominance of rocks of Coniston Grit type in the Mell Fell Conglomerate—would be more readily explicable in terms of a pre-Bala erosion and unconformity in this part of the District.

The Caledonian folds in general follow the normal west-south-west–east-north-east trend but there are significant exceptions which are concentrated in the extremities of the inlier: these are referred to below.

The folding varies greatly in intensity in all the three major groups. In many cases this is related to the lithological characters of the rock but there appear to be other, more general factors. Simple, major structures, such as the Nan Bield Anticline and the broad, open Scafell Syncline, contrast with the belt of steep, almost closely packed isoclinal folds associated with reversed faults farther south, as illustrated on sections by Mitchell (1934, pl. XIV; 1940, fig. 3, p. 315).

Hartley has indicated the position of another belt of sharp folds of small amplitude between the broad folds of the Helvellyn area and the rather gentle south-south-easterly dipping lower beds cropping out on the northern margin of the main Borrowdale outcrop.

Departures from the regional Caledonian fold-trend are found in the extreme south-west where a progressive change occurs from east-north-east about Ambleside through north-east by north about Coniston to somewhat north of north-north-east in the anticlinal inlier of Lower Ordovician east of the Duddon estuary. A swing of the fold axes in the opposite direction is found in the extreme north-east where the normal east-north-east trend through Skiddaw becomes easterly north and south of Carrock Fell and east-south-east in the area east and south-east of that hill. Similar changes of strike occur in the cleavage. These changes in direction produce an eastward narrowing of the width of the outcrop of the main anticlinal belt of Skiddaw Slates which gives an impression of easterly pitch that is supported by the presence of the isolated outcrop of volcanics on Eycott Hill. The latter can be regarded as part of an easterly pitching synclinal fold within the main anticlinorium.

The change in strike may continue beneath the newer rocks in the Vale of Eden, and indeed probably does, for it would then link up with the east–west strike of the Silurian of the Howgill Fells to the south-east of Shap. The easterly pitch recognisable along the Skiddaw axis does not recur in the folds within the Borrowdale Volcanic Series to the south, for Skiddaw Slates appear in the lower reach of the Ullswater Valley, along a five-mile strip east of Haweswater, and immediately beneath the Carboniferous (see Harkness, 1863, fig. 4, p. 127). These outcrops rather suggest a westerly pitch. It is noteworthy and, perhaps, significant that a similar series of inliers of Skiddaw Slates crop out on the western edge of the inlier. These are, from south to north: the Greenscoe area north of Dalton, Black Coombe, and the metamorphosed slates adjacent to the Eskdale Granite east of Ravenglass (Rose, 1937, p. 50, fig. 7).

It may be suggested that the curved (concave to the south) trend of the Caledonian strike, as indicated by the outcrop of the basal Bala, reveals the effect of a greater north-north-west directed compression in the centre than on the flanks. It would be tempting to relate this to the presence of the intrusive masses of Eskdale and Ennerdale in the west and Shap (and the Haweswater diorite) in the east, were there not a considerable body of evidence that the emplacement of these was later than the main crustal movements. (A later, post-intrusion recurrence of compression cannot be excluded.)

A different approach, suggestive of greater compression in the central region, is provided by a small map by Postlethwaite (1890–1), in which are shown the areas of 'Highly cleaved ashes and breccias' as two elongated lenses, one in the north, between Honister and Borrowdale, and the other from the head of the Duddon Valley by Tilberthwaite to the Troutbeck Valley. (The latter could have been continued farther to the east.)

It is reasonable to suppose that the greater compression in the central area would increase the thickness of the folded volcanic rocks and that this might be expressed in deeper downwarping of the disharmonic Skiddaw Slates–Borrowdale junction in the centre than on the east and west extremities of the Lower Palaeozoic inlier.

Folding in the Silurian varies according to the nature of the rocks. Closely packed folds are common (e.g. Blackie, 1933, fig. 6). I measured a good section illustrating such folding in Brathay Flags in a Manchester Corporation Waterworks tunnel at Murthwaite on the east side of Long Sleddale.

Cleavage intensity varies greatly both because of local and regional influences. The cleavage distribution was studied by Ward, who showed on a small-scale map (1876, pl. IX, facing p. 68) the position of cleavage 'anticlines' and 'synclines' for the Keswick sheet (O.S. 101 SE.) and briefly discussed the relation of these to the fold-axes. Hartley (1935, p. 59) discussed the divergence between cleavage, strike and axes of cleavage-folds in the Langdale area. Farther west, Mitchell (1940) found that cleavage dips generally to the north-north-west whereas axial planes in the folded strata dip south-south-east. He has found that this is also the case in general in the eastern part of the district and has suggested that possibly the pressures producing the folding and the cleavage were not contemporaneous. In the Helvellyn area, Hartley (1942) found that cleavage is parallel to the axial planes of the folds.

Diverse views of the age of the cleavage relative to the emplacement of the major intrusions have been expressed. A post-cleavage age for intrusion appears to be established in some instances, but in others evidence for a pre-cleavage age has been advanced (e.g. Hancox, 1934). The great time involved in an orogenic period may well have involved renewal of great compressive forces. A general, regional cleavage picture is not yet available.

Intrusions. Opinions as to the age and mode of emplacement of the intrusions have fluctuated greatly. Ward's conclusion (1875, p. 590), based on field and microscopic study of the granitic masses, has a strongly modern note: ' . . . in all probability the heated mass below partly ate its way upward, to within reach of the volcanic series *the rocks of which were metamorphosed to such an extent as to assume the granitic form*.' [Author's italics.]

Systematic petrographic accounts of the major intrusions appeared in the years 1890–1910 by Harker; Shap Granite, Carrock Fell Complex and minor intrusions—Rastall; Ennerdale Granophyre and Skiddaw Granite—Dwerryhouse; Eskdale Granite. The attribution of a laccolithic form to many of the intrusions was in accord with the current views on the importance of this type of intrusion. The Ennerdale Granophyre has the flat roof and vertical 'sides' of a stock or plug (Hollingworth *in* Eastwood *et al.*, 1931, fig. 3) while, in the Skiddaw and Eskdale Granites, unroofing is not yet complete. In the case of the Skiddaw Granite, the great extent of the aureole suggests that unroofing is in an early stage (see Eastwood, 1946, fig. 6) but the slope of the outer crust of metamorphism gives a clue to the shape of the mass. The unroofing of the Eskdale mass is much farther advanced and the resurvey of the western part by Rose gives indication of a steep western margin. The evidence for concealed intrusions at depth (see Rose below) may be noted here, and the possibility of a large mass related to the Lake District dome as a whole may also be mentioned.

Harker, followed by Marr, divided the intrusions into two groups: an older suite represented by the Ennerdale Granophyre, the St. John's Vale Microgranite, and various minor intrusions related to the Volcanic Series; and a younger suite comprising the granites of Shap, Eskdale and Skiddaw, the Carrock Fell Complex and various dykes.

Green (1917, 1918), however, claimed that all the major intrusions, with the exception of Shap, were of Ordovician age, a contention which has not been upheld by subsequent work during the resurvey of the western and northern areas (see Eastwood *et al.*, 1931; and Hollingworth, 1937).

The Eskdale Granite mass contains a variety of rock-types including a granodioritic type with abundant biotite-rich clots that have probably been derived from the volcanic rocks (Rose, 1937, pp. 47–61; see also Simpson, 1934).

The Ennerdale Granophyre comprises a considerable range of rocks of granophyric affinities as well as more hornblende-rich dioritic types. Mutual relations vary from sharp to merging contacts. Revision of the original work on this mass has so far been in the western half only (Hollingworth *in* Trotter *et al.*, 1937, pp. 41–7).

The petrology of the Shap Granite was reinvestigated by Grantham (1928) who recognised a sequence of intrusions of increasing acidity. The Skiddaw Granite and the Carrock Fell Complex have been re-surveyed by me and an interim summary of his conclusions has been published (Hollingworth, 1937). Hancox (1934) has described the Haweswater Dolerite as a plug-like mass.

The mode of emplacement of the igneous bodies present many problems of interest. The Skiddaw Granite appears to have replaced the country rock, generally penetrating to higher altitudes in the anticlinal areas. There is little evidence of chemical as distinct from mechanical replacement. Rock-types of sedimentary origin in the granite are rare, although large-scale metasomatism of the surviving country-rock envelope is superposed on a thermal metamorphism.

The Carrock Complex presents interesting problems of emplacement involving, it is thought, large vertical displacements of the roof rocks (Borrowdale Volcanic rocks and Drygill Shales) along an elongate fracture-belt situated, perhaps significantly, at the bend in the strike of the Caledonian folds from east-north-east to east-south-east.

4. CONCLUSIONS

It will be evident that much work remains to be done on the succession and structure of the Lower Palaeozoic rocks. Some co-ordinated effort seems highly desirable especially if this should lead to an infilling of the gaps between the modern maps and so make possible the publication of a map of the whole district. It is a very regrettable fact that no modern colour-printed map of the area on a suitable scale is available to the public for this much visited and geologically classic region.

Perhaps it is not out of place to suggest here that some body of interested research workers should be brought together with such an objective in view. The results of the Association's Weald Research Committee is an excellent example of what can be achieved by mutual help.

REFERENCES

(Important references to stratigraphy and palaeontology of the Lower Palaeozoic are given in Marr's *Geology of the Lake District*. In general, references to mining and mineral veins, and to the interesting field of mineralogy, in which valuable additions have been made in recent years, have been omitted for reasons of space. Neither have many papers dealing with geomorphological topics, glacial geology and post-glacial changes been included.)

Aveline, W. T. 1888. The geology of the country around Kendal, Sedburgh, Bowness and Tebay. *Mem. Geol. Surv.*

Blackie, R. C. 1932–3. The Silurian Rocks of the Kentmere District, Westmorland. *Proc. Liverpool Geol. Soc.*, **16**, 88–105.

Capewell, J. G. 1954. The Post-Silurian, pre-marine Carboniferous sedimentary rocks of the eastern side of the English Lake District. *Proc. Geol. Soc. Lond.*, No. 1507, p. xlii.

Dixon, E. E. L. 1925. *In* 'Summary of Progress for 1924'. *Mem. Geol. Surv.* 70–1.

Dwerryhouse, A. R. 1909. Intrusive rocks in the neighbourhood of Eskdale. *Quart. Journ. Geol. Soc. Lond.*, **65**, pp. 55–80.

Eastwood, T., E. E. L. Dixon, S. E. Hollingworth & B. Smith. 1931. The geology of the Whitehaven and Workington District. *Mem. Geol. Surv.*

————. 1946. British Regional Geology: Northern England, 2nd Ed. *Mem. Geol. Surv.*

Elles, G. L. 1933. The Lower Ordovician Graptolite Faunas with special reference to the Skiddaw Slates. 'Summary of Progress' for 1932, Pt. 2. *Mem. Geol. Surv.*

Grantham, D. R. 1928. The petrology of the Shap Granite. *Proc. Geol. Assoc.*, **39**, 299–331.

Green, J. F. N. 1911. *The Older Palaeozoic Succession of the Duddon Estuary*, London.

————. 1915*a*. The structure of the Eastern Part of the Lake District. *Proc. Geol. Assoc.*, **26**, 195–223.

————. 1915*b*. The garnets and streaky rocks of the English Lake District. *Min. Mag.*, London, **17**, 207–17.

————. 1917. The age of the chief intrusions of the Lake District. *Proc. Geol. Assoc.*, **28**, 1–30.

GREEN, J. F. N. 1918. The Skiddaw Granite: A structural study. *Proc. Geol. Assoc.*, **29**, 126–36.

————. 1919. The vulcanicity of the Lake District. *Proc. Geol. Assoc.*, **30**, 153–82.

————. 1920. The geological structure of the Lake District. *Proc. Geol. Assoc.*, **31**, 109–26.

HADFIELD, G. S. & H. C. M. WHITESIDE. 1936. The Borrowdale Volcanic Series of High Rigg and the adjoining Low Rigg Microgranite. *Proc. Geol. Assoc.*, **36**, 42–64.

HANCOX, E. G. 1934. The Haweswater Dolerite, Westmorland. *Proc. Liverpool Geol. Soc.*, **16**, 173–97.

HARKER, A. 1894. Carrock Fell. A study in the variation of igneous rock-masses. Part I: The Gabbro. *Quart. Journ. Geol. Soc. Lond.*, **50**, 311–37.

————. 1895. Carrock Fell. A study in the variation of igneous rock-masses. Part II: The Carrock Fell Granophyre. Part III: The Grainsgill Greisen. *Quart. Journ. Geol. Soc. Lond.*, **51**, 125–48.

————. & J. E. MARR. 1891. The Shap Granite and associated rocks. *Quart. Journ. Geol. Soc. Lond.*, **47**, 266–328.

HARKNESS, R. 1863. On the Skiddaw Slate Series. *Quart. Journ. Geol. Soc. Lond.*, **19**, 113–40.

HARTLEY, J. J. 1925. The succession and structure of the Borrowdale Volcanic Series as developed in the area lying between the Lakes of Grasmere, Windermere and Coniston. *Proc. Geol. Assoc.*, **36**, 203–26.

————. 1932. The volcanic and other igneous rocks of Great and Little Langdale. *Proc. Geol. Assoc.*, **43**, 32–69.

————. 1941. The geology of Helvellyn and the southern part of Thirlmere. *Quart. Journ. Geol. Soc. Lond.*, **97**, 129–62.

HITCHEN, C. S. 1934. The Skiddaw Granite and its residual products. *Quart. Journ. Geol. Soc. Lond.*, **90**, 158–200.

HOLLINGWORTH, S. E. 1931. The glaciation of Western Edenside and adjoining areas and the drumlins of Edenside and the Solway Basin. *Quart. Journ. Geol. Soc. Lond.*, **87**, 281–359.

————. 1937. High level erosional platforms in Cumberland and Furness. *Proc. Yorks. Geol. Soc.*, **23** (3), 1936, 159–77.

————. 1938. Carrock Fell and adjoining areas. *Proc. Yorks. Geol. Soc.*, **23** (for 1937), 208–18.

MARR, J. E. 1910. Palaeozoic and Neozoic Times in the Lake District and neighbourhood. '*Geology in the Field.*' *Geol. Assoc.*, 624–60.

————. 1916. *The geology of the Lake District.* Cambridge.

MCCONNELL, R. B. 1939. Residual erosion surfaces in mountain ranges. *Proc. Yorks. Geol. Soc.*, **24** (for 1938), 76–97.

MILLER, A. A. 1939. Preglacial erosion surfaces round the Irish Sea Basin. *Proc. Yorks. Geol. Soc.*, **24** (for 1938), 31–59.

MITCHELL, G. H. 1929. The succession and structure of the Borrowdale Volcanic Series in Troutbeck, Kentmere and the western part of Long Sleddale (Westmorland). *Quart. Journ. Geol. Soc. Lond.*, **85**, 9–44.

————. 1930. Notes on the petrography of the Borrowdale Volcanic Series of Kentmere. *Quart. Journ. Geol. Soc. Lond.*, **86**, 1–8.

————. 1934. The Borrowdale Volcanic Series and associated rocks in the country between Long Sleddale and Shap. *Quart. Journ. Geol. Soc. Lond.*, **90**, 418–44.

————. 1940. The Borrowdale Volcanic Series of Coniston, Lancashire. *Quart. Journ. Geol. Soc. Lond.*, **96**, 301–19.

PENNINGTON, W. 1947. Lake sediments, pollen diagrams from the bottom deposits of the North Basin of Windermere. *Proc. Roy. Soc. Lond.* (Ser. B), 233, 137–75.

POSTLETHWAITE, J. 1890–1. The cleaved ashes and breccias of the Volcanic Series of Borrowdale. *Trans. Cumb. West. Assoc. Adv. Lit. Sci.*, No. 16, 41–54.

RASTALL, R. H. 1906. The Buttermere and Ennerdale Granophyre. *Quart. Journ. Geol. Soc. Lond.*, **62**, 253–74.

————. 1910. The Skiddaw Granite and its metamorphism. *Quart. Journ. Geol. Soc. Lond.*, **66**, 116–40.

RASTALL, R. H. & W. H. WILCOCKSON. 1917. Accessory minerals of the granitic rocks of the Lake District. *Quart. Journ. Geol. Soc. Lond.*, **71** (for 1916), 592–622.

SIMPSON, B. 1934. The petrology of the Eskdale (Cumberland) Granite. *Proc. Geol. Assoc.*, **45**, 17–34.

SMITH, B. 1912. On the glaciation of the Black Combe District. *Quart. Journ. Geol. Soc. Lond.*, **68**, 402–48.

————. 1924. The unconformable base of the Coniston Limestone Series in the Lake District. *Geol. Mag.*, London, **61**, 163–67.

TROTTER, F. M. 1944. The age of the ore deposits of the Lake District and the Alston Block. *Geol. Mag.*, London, **81**, 223–9.

————, S. E. HOLLINGWORTH, T. EASTWOOD & W. C. C. ROSE. 1937. The geology of the Gosforth District. *Mem. Geol. Surv.*

WALKER, E. E. 1904. Notes on the garnet-bearing and associated rocks of the Borrowdale Volcanic Series. *Quart. Journ. Geol. Soc. Lond.*, **60**, 70–105.

WARD, J. C. 1876. The geology of the northern part of the Lake District. *Mem. Geol. Surv.*

EXPLANATION OF FIGURE

Fig. 1 (p. 394). D: Dixon in Eastwood *et al.*, 1931. E: Eastwood (unpublished). Es: Dwerryhouse, 1909. Simpson, 1934. G1–3: Green 1918, 1915, 1917. H1: Harker, 1894, 1895. Hollingworth, 1938. Ha: Hartley, 1925, 1932, 1941. Hn: Hancox, 1934. Ho1–3: Hollingworth *in* Eastwood *et al.*, 1931, *in* Trotter *et al.*, 1937 and unpublished (Ho3). H and W: Hadfield and Whiteside 1936. M1–4: Mitchell 1929, 1934, 1940 and unpublished (M4). O: Oliver unpublished. R1–3: Rose *in* Trotter *et al.*, 1937, and unpublished (R2 and R3). Ra: Rastall 1906, 1910. S: Harker & Marr, 1891. T: Trotter unpublished.

The Sequence and Structure of the Skiddaw Slates in the Keswick–Buttermere Area

by W. C. C. ROSE

Received 11 June 1954

THE SKIDDAW SLATES in this area occupy part of the core of the main anticlinal axis of the Lake District, the general trend of which is in an east-north-east and west-south-west direction through Skiddaw, across Bassenthwaite, and thus to Loweswater and north of Ennerdale. In the neighbourhood of Keswick and Honister Pass the amplitude of the main anticline, as indicated by the general dip of the Borrowdale Volcanic Series, is comparatively low, the inclination of the beds being generally south-eastwards at about 20–30°. On the northern limb of the anticline, however, for instance at Binsey north of Skiddaw and in the gorge of the Caldew, the dip of the Borrowdale Volcanic Series is at a high angle and locally inverted.

Within the outcrop of the Skiddaw Slates the general anticlinal structure is profoundly modified by the development of a succession of tightly packed folds accompanied by overfolding, faulting and thrusting and by severe contortion and cleavage.

Many interpretations have been placed on the stratigraphical succession within the Skiddaw Slates, near Keswick, since the original work by Sedgwick and by Harkness about the middle of the last century. Although graptolite assemblages are well known in the Skiddaw Slates of this area, they are restricted to a few localities only, and notwithstanding efforts by palaeontologists (notably Marr and Elles) to establish the existence of a succession of graptolite zones, this has been of little help in elucidating the stratigraphy and structure.

Speaking generally, the Skiddaw Slates in the Keswick–Buttermere area comprise a lower arenaceous group of rocks and an upper argillaceous group, the outcrop of both of which is repeated several times by folding and faulting:

Sequence:	
Borrowdale Volcanic Series	
Skiddaw Slates (Skiddavian):	*Thickness*
Mosser-Kirkstile Slates	+2500 ft.
Loweswater Flags (base not seen)	+4000 ft.

Differences in the lithology of the two groups when traced from the extreme north-west to the junction with the overlying Borrowdale Volcanic Series in the south-east—differences which had led earlier workers to suspect the presence of several rock-groups within the Skiddaw Slates or even of rocks of lower age than Lower Ordovician—are now ascribed to original lateral variations in lithology and, more particularly, to subsequent changes due to thermal metamorphism and earth movements. It is reasonably certain that the lowest rocks exposed in the area (the base is not seen) form an integral part of the arenaceous group (Loweswater Flags) which, at higher stratigraphical levels within it, contains the earliest of the graptolite faunas. In other words, it seems unlikely that, as was at one time suggested, Upper Cambrian rocks are present, and even more unlikely that rocks of Pre-Cambrian age are exposed.

The whole of the area is intensely compressed into tightly packed folds; overfolding, thrusting and isoclinal folding are common. In surface outcrops the beds are frequently seen to be vertical or to dip at high angles, and the true regional dip is not often easily discernible. It will readily be appreciated, therefore, that in such circumstances the key to the succession lies in correctly identifying the position of the major folds, and in ascertaining whether they are synclinal or anticlinal in form; in this regard evidence provided by false-bedding (fortunately not uncommon in the arenaceous beds) is invaluable.

The Loweswater Flags crop out in three main belts, trending in an east-north-east–west-south-west direction and marking the position of anticlinal axes. A fourth outcrop, probably indicating a fourth anticline, trends in a similar direction through Watch Hill, to the north of the Embleton Valley, between the foot of Bassenthwaite Lake and Cockermouth. In general the group consists of flaggy sandstones and grits with interbedded greenish-grey slates. The beds are more arenaceous in the lower part of the Group, the grits and flaggy beds being coarser and thicker. The upper beds are thinner-bedded and pass gradually into the Mosser-Kirkstile Group above.

The Mosser-Kirkstile Slates occupy intervening synclinal areas between the anticlines. They are an argillaceous group consisting of slates usually characterised by a fine light and dark striping or banding well seen on water-worn surfaces. The lighter bands are often silty and, by an increase in number and thickness towards the base, mark the passage into the Loweswater Flags below. In the northern part of the area the slates of this Group tend to be greenish-grey in colour whereas in the central and southern part of the area they tend to be blue-black, but there are many exceptions.

In a traverse from the north the first structure is a sharp upfold of Loweswater Flags, both limbs of which are inverted in places. It extends along the southern side of the Embleton Valley and is marked by the line of fells—Sale Fell, Whinfell, Mosser Fell, Burn Bank Fell and Carling Knot (Loweswater). This is succeeded south-eastwards by a narrow infold of Mosser-Kirkstile Slate extending through Wythop Moss and Lorton to Loweswater, followed by a wide belt of Loweswater Flags occupying the country in the neighbourhood of Barf, Whinlatter Pass, Whiteside, Grisedale Pike and Brackenthwaite. This belt is generally anticlinal in structure but is complicated by repeated overfolding and faulting producing repetition of outcrops.

The main outcrop of the Mosser-Kirkstile Slates in the area occupies a belt of country two to three miles wide extending from Braithwaite, west of Keswick, through the group of mountains around Grasmoor, across Crummock Water to Mellbreak, Hen Combe and Gavel Fell to Blakefell. This is a sharply infolded and tightly compressed syncline, the general structure of which is shown in the section (Fig. 1). Part of the outcrop of the Mosser-Kirkstile Slates in this syncline is within a well-defined metamorphic aureole. Here the slates are significantly altered to a lighter coloured, hard, brittle rock usually showing minute darker spots. This is a rock-type which has been named by Dixon (*in* Eastwood *et al.*, 1931) as 'Blakefell Mudstone'. Although he recognised that it had been subsequently metamorphosed, he thought that it represented an original rock group of the Skiddaw Slates equivalent in age to the Loweswater Flags into which it passed laterally. Earlier workers had also mapped this belt of altered rocks as a distinct lithological unit occupying a stratigraphical horizon, and Clifton Ward referred to these rocks as the 'Grasmoor Grits', an older rock-group than the Loweswater Flags. Detailed mapping has revealed that the outcrop of the so called 'Blakefell Mudstone' is, in fact, transgressive to the general structure and it is clear in the field that it represents a zone of thermal alteration produced by an intrusion which, however, nowhere appears at the surface. The aureole can be traced from Barrow and Causey Pike in the east, through Grasmoor and across Crummock Water to Mell Break and Blake Fell, a distance of about eight miles. It varies from one half to two miles in width. Having regard to the remarkable persistence in direction of the boundaries of this aureole, and the uniformity of the degree of alteration vertically through a height-range of nearly 2500 ft. (on Grasmoor), it must be presumed that the intrusion is elongated in plan, but stock-like in form, with relatively steep sides; also that its surface lies at no great depth and in contour bears some relation to the existing topography. Part of the southern boundary of aureole near Causey Pike is a thrust of later age than the intrusion.

Southwards the Braithwaite syncline gives way to the anticlinal area of Loweswater Flags outcropping in the region of Newlands, Cat Bells, Little Dale, Robinson and Buttermere. The general structure of this area, which is complicated by severe overfolding and thrusting, is shown in the section.

Between the anticlinal area of Loweswater Flags just described and the outcrop of the Borrowdale Volcanic Series along the line Grange, Dale Head, Honister Pass and Warnscale Bottom, there is an outcrop of Mosser-Kirkstile Slates presumably occupying a syncline but which has been so compressed, cleaved, and sheared that details of the structure are difficult to make out. It probably includes some sharp upfolds of highly sheared Loweswater Flags. In one or two places, where the junction between the Borrowdale Volcanic Series and the Skiddaw Slates can be seen, it appears to be normal and unaffected by faulting. Clearly, however, a substantial thickness of the upper part of the Skiddaw Slates is missing in this area and it is believed that large-scale movements, probably of the low-angled type, described by Marr as 'lag faults', traverse the outcrop of the Mosser-Kirkstile Slates at or near the junction.

REFERENCES

EASTWOOD, T., E. E. L. DIXON, S. E. HOLLINGWORTH & B. SMITH. 1931. The geology of the Whitehaven and Workington District. *Mem. Geol. Surv.*

ELLES, G. L. 1898. The Graptolite-Fauna of the Skiddaw Slates. *Quart. Journ. Geol. Soc. Lond.*, **54**, 463–539.

———. 1933. The Lower Ordovician Graptolite Fauna with special reference to the Skiddaw Slates. Summary of Progress for 1932; Pt. 2, *Mem. Geol. Surv.*

MARR, J. E. 1916. *The geology of the Lake District.* Cambridge.

Note on the Succession in the region around the head of Borrowdale, Cumberland

by R. L. OLIVER

Received 11 June 1954

THE WRITER has recently completed a survey of twenty square miles in the central part of the Lake District and the following notes are intended as a preliminary summary of lithological features of the main divisions in the northern part of the area mapped.

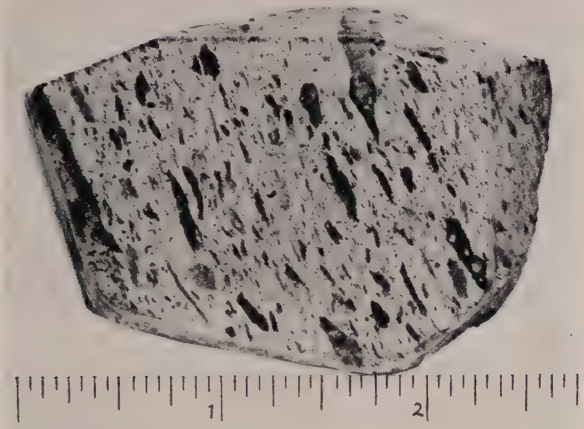
The sequence described lies on the northern limb of the major syncline extending east-north-east through the Scafell area. Bedding dips at moderate angles (rarely more than 50°) consistently to the south-south-east except for minor folds in the Airy's Bridge Group. Faults, which are mainly vertical and probably tear-faults, trend most commonly north-west–south-east, but a few trend north–south or north-north-east–south-south-west. Fracture, or strain-slip, cleavage is well developed in certain areas. Joints are numerous, but the joint pattern shown by 500 plotted joints is obscure.

Andesites (Grey Knotts type). The lowest beds mapped are a group of andesites which outcrop to the south of, and above, the well-known slate-belt of Honister Crag. These are thought by the writer to be the equivalent of Hartley's (1932) Mosedale Andesites of Langdale and they may also correspond to the Lower Borrowdale Andesites of Green (1919).

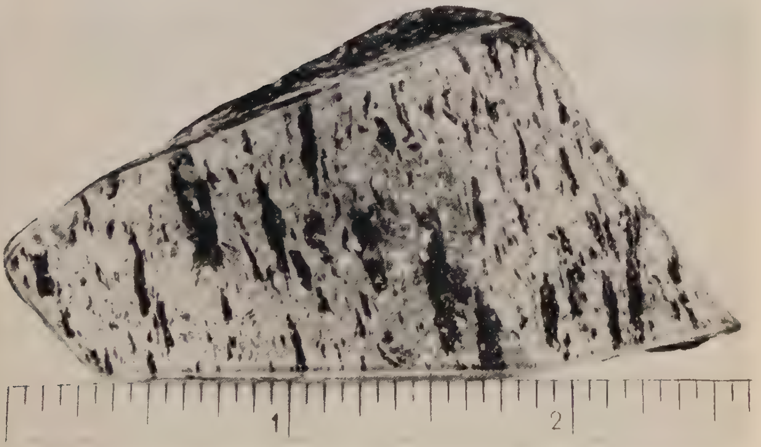
The mapped andesites are characteristically porphyritic, with phenocrysts of felspar up to 3 mm. diameter, and clusters of pyroxene which is usually altered to amphibole and chlorite, lying in a fine-grained, often once glassy matrix. A nondescript purplish-red weathered surface is common. The flows are commonly 50–60 ft. thick, with scoriaceous, vesicular and flow-brecciated tops and may be separated by horizons of tuff. Some flows are almost entirely scoriaceous, with but three or four feet of massive lava near the base. The scoriaceous rock is usually much more strongly mineralised with epidote, chlorite and quartz than the massive lava, due presumably to its greater permeability, and is then distinguishable only with difficulty from unbedded tuff. The brecciated tops of the flows are distinctly red in places, due to oxidation, and testify to their sub-aerial extrusion. Flow-banding in the more massive lava is common and develops occasionally into distinct platy jointing. Locally, on Brandreth and Grey Knotts, differentiation of flows into vesicular scoriaceous tops and more massive bottoms is accompanied by a mineral separation; thus large felspar crystals, up to 4 mm. diameter, have segregated in the upper part of the flow after extrusion, so giving the impression of alternating flows of different type. In one exposure, a succession of very thin flows has resulted in a layered alternation of the two varieties, each only an inch thick. In the crags to the south of Stonethwaite, Borrowdale, on the line of section, the lower andesitic lavas are lighter in colour than the typical andesites and rather rhyolitic in appearance. They are garnetiferous in part.

Airy's Bridge Group. The main feature of these rocks is a remarkable streaky structure 'occurring both in lavas and fragmental rocks' (Marr, 1916, p. 23). The streaks are mainly of two kinds: 1, Flow-banding in rhyolite and rhyodacitic lavas, accentuated in places by the deposition of secondary minerals such as quartz, which may project on the weathered surface like elongated fragments; 2, Parallelism of deformed fragments in *welded tuff*. In both rocks, these streaks, apart from local contortions of flow-banding, are parallel to the bedding of overlying or underlying normal tuff. Less commonly, shearing stresses are responsible for the development in the rock of parallel planes which, where intermittent, appear as 'streaks'. Such 'streaks' and bedding usually intersect obliquely. The deformed fragments, mentioned under item 2, above, have been flattened in the plane of the bedding, are disc-like in shape, and so appear on most planes of fracture as lenticular streaks, up to six inches in length and two inches across. They are chloritic, green to almost black in colour, and are commonly weathered below the level of the surrounding matrix.

That the Lake District 'streaky rocks' are in part welded tuffs has not been postulated hitherto, though Howell Williams (personal communication, 1952) considers that welded tuffs outcrop in North Wales. Welded tuffs are considered to consist of volcanic fragmentary material which has been ejected at a temperature sufficiently high for the fragments to have retained a degree of plasticity and thus to be welded together when deposited. Commonly the hot fragments are considered to have been emitting vapour during 'extrusion', forming a vaporous cushion round each fragment, facilitating flow of the fragmentary material as in the *nuées ardentes* of Mont Pelée and in the Valley of Ten Thousands Smokes. By analogy with this, therefore, the flattened shape of the fragments in the Lake District rocks concerned may be due in part perhaps to flow; though, on the other hand, the disc-like shape of the fragments is suggestive of deformation due to the weight of overlying material, as this has already been suggested by G. H. Mitchell (1929, p. 23) for similar rocks in the south-eastern Lake District. Among welded tuffs from different parts of the world the New Zealand 'owharoite', a variety of ignimbrite, resembles most closely the Lake District examples



A. A variety of 'owharoite', Ignimbrite, from Owharoa, North Island, New Zealand



B. Ignimbrite tuff of rhyolite or rhyodasitic composition. Near Slate Crag, 500 yds. west of Bowfell summit, Cumberland

Scales of both illustrations are in inches

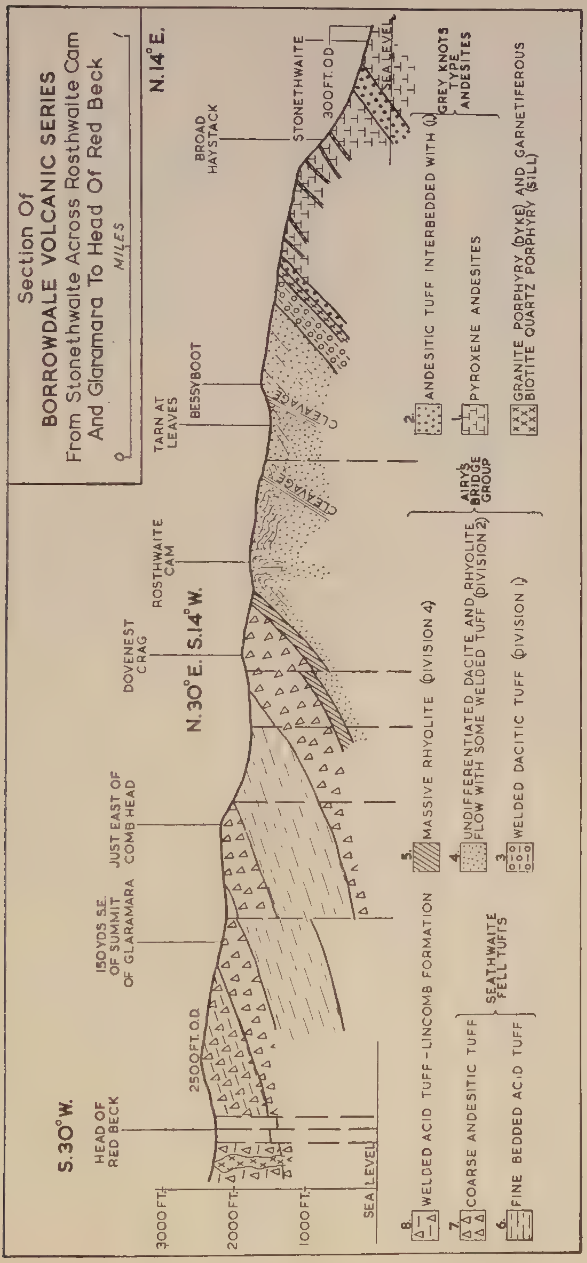

Section Of
BORROWDALE VOLCANIC SERIES
From Stonethwaite Across Rosthwaite Cam
And Glaramara To Head Of Red Beck
MILES
0
1
N.14°E.
BROAD HAYSTACK
STONETHWAITE
300FT. O.D
SEA LEVEL
BESSYBOOT
TARN AT LEAVES
CLEAVAGE
CLEAVAGE
ROSTHWAITE CAM
DOVENEST CRAG
S.14°W.
N.30°E.
JUST EAST OF COMB HEAD
150YDS S.E. OF SUMMIT OF GLARAMARA
2500FT. O.D.
HEAD OF RED BECK
S.30°W.
3000FT.
2000FT.
1000FT.
SEA LEVEL
8. WELDED ACID TUFF - LINCOMB FORMATION
7. COARSE ANDESITIC TUFF
6. FINE BEDDED ACID TUFF
SEATHWAITE FELL TUFFS
5. MASSIVE RHYOLITE (DIVISION 4)
4. UNDIFFERENTIATED DACITE AND RHYOLITE FLOW WITH SOME WELDED TUFF (DIVISION 2)
3. WELDED DACITIC TUFF (DIVISION 1)
AIRY'S BRIDGE GROUP
2. ANDESITIC TUFF INTERBEDDED WITH (1)
1. PYROXENE ANDESITES
GREY KNOTS TYPE ANDESITES
GRANITE PORPHYRY (DYKE) AND GARNETIFEROUS BIOTITE QUARTZ PORPHYRY (SILL)

Fig. 1. Section of Borrowdale Volcanic Series from Stonethwaite to Red Beck

in general appearance (see Plate facing p. 408), and the deformation of the fragments in the New Zealand rock has been considered a flattening resulting from pressure of the overlying material. The distinction between flow-rocks and welded tuffs within the Airy's Bridge Group of the Lake District is impossible in places, as recognised previously by E. E. Walker (1904, p. 94), and as admitted also by Howell Williams (1927, p. 373) concerning similar rocks in North Wales. In the New Zealand 'owharoite' of late Tertiary age, the streaked fragments are all of glass, and it is considered by the present writer that the chlorite fragments in the Lake District rocks were also originally of glass, and subsequently altered. The formation of chloritic fragments from a glass of rhyolitic or rhyodacitic composition would involve a considerable chemical change, necessitating a substantial reduction in silica and the addition of iron and magnesia, but it is nevertheless possible.

The Airy's Bridge Group has been separated into several divisions, the lowermost of which consists essentially of welded tuff, overlain by the major part (division 2) of the Group, composed of both flows and welded tuffs. Division 3 consists of rather coarse tuffs of limited extent and an uppermost division, 4, consists of rather massive rhyolite, flow-brecciated in part. Divisions 3 and 4 are locally missing. Typically the rocks of the Airy's Bridge Group, ranging in composition from rhyolite to dacite, are dark- or greenish-grey in colour, though some of the welded tuffs of the lower divisions have a vitreous base which is almost black. A rather flinty texture is characteristic. The only conspicuous phenocrysts in the field are of scattered felspar and garnet, the latter, up to ¼ in. diameter, being concentrated most abundantly in the coarsest tuffs of the third division. Columnar jointing is well developed in places in the rhyolite flows at the base of division 2, and also in the welded tuffs higher in the Group.

Seathwaite Fell Tuffs. This group has been divided into lower and upper divisions of coarse to medium grained andesitic tuff separated by fine-grained, white weathered hornstone. The lowermost division can be clearly distinguished in the field from the underlying Airy's Bridge Group by the absence of strong silicification characteristic of the latter, and odd fragments of the underlying rhyolite have been incorporated in the lower part of the Seathwaite Fell Tuffs. The middle hornstone, well-bedded for the most part, is considered to be a fine tuff, which was deposited sub-aqueously as mud; several sedimentary features such as suncracked layers (in cross section) and a contortion of the bedding due to sub-aqueous slumping can be seen. The rocks of the uppermost division are well-bedded tuffs which are finer grained than those of the lower division. Their sub-aqueous deposition can be recognised by the common occurrences of current-bedding. Extensive development of secondary minerals, such as epidote and quartz, is found throughout the lower and upper divisions.

Lincomb Tarns Formation. The Lincomb Tarns Formation consists essentially of silicified welded rhyolitic tuffs in which the 'streaky' structure is not so well shown as by the welded tuffs of the Airy's Bridge Group. The silicification of the Lincomb Tarns Formation is concretionary in places, e.g. just south of the head of Red Beck on the Glaramara Summit ridge (Fig. 1). Associated with some of the concretionary silica is yellow-green epidote, and more rarely brownish pink secondary felspar. The development of all three minerals is perhaps best seen at the base of the Lincomb Tarns Formation on the spur running north-west from Great End. Small garnets are scattered sporadically throughout this formation.

Esk Pike Hornstone. The restriction of this, the youngest formation in the succession, to the summits, or near summits, of the mountains in the broad axial region of the syncline indicates the low angle of dip of the rocks concerned. It is not present in the line of section in Fig. 1.

The Esk Pike Hornstone is greenish-grey when fresh and typically white on the weathered surfaces. In these details it resembles the Seathwaite Fell Tuffs hornstone. On Allen Crags sub-aqueous slumping has resulted in the beds being twisted and displaced in a particularly chaotic manner.

Intrusive rocks. A pink granite porphyry dyke-rock cuts the volcanic rocks of the line of section. It consists essentially of 60–70% of albite together with quartz and clots of chloritised biotite which are locally visible in the hand specimen.

A thin sill of garnetiferous biotite-quartz-porphyry, cross-cutting in places, is also present. It is brownish-green in colour and characterised by the presence of fairly abundant euhedral garnets.

Porphyry, porphyritic dolerite and other basic rocks also occur within the area here considered.

REFERENCES

GREEN, J. F. N. 1919. The vulcanicity of the Lake District. *Proc. Geol. Assoc.*, **30**, 153–82.

HARTLEY, J. J. 1932. The volcanic and other igneous rocks of Great and Little Langdale. *Proc. Geol. Assoc.*, **43**, 32–69.

MARR, J. E. 1916. *The geology of the Lake District.* Cambridge.

MITCHELL, G. H. 1929. The succession and structure of the Borrowdale Volcanic Series in Troutbeck, Kentmere, and the western part of Long Sleddale (Westmorland). *Quart. Journ. Geol. Soc. Lond.*, **85**, 9–44.

WALKER, E. E. 1904. Notes on the garnet-bearing and associated rocks of the Borrowdale Volcanic Series. *Quart. Journ. Geol. Soc. Lond.*, **60**, 70–105.

WILLIAMS, H. 1927. The geology of Snowden (North Wales). *Quart. Journ. Geol. Soc. Lond.*, **83**, 346–431.

Note on Metasomatic changes in the rocks adjacent to the Shap Granite

by R. J. FIRMAN

Received 11 June 1954

THE PETROGRAPHY of the Shap Granite and its thermal aureole has been described principally by Harker & Marr (1891; 1893) and Grantham (1928) has discussed the variations within the granite.

The present geochemical study was undertaken to determine the character and extent of metasomatism around the granite. It has been demonstrated that Si and K were introduced into the country-rocks causing some silicification and the formation of biotite in the contact hornfelses; but more striking mineralogical changes took place in the wall-rocks along a pre-granite joint-system.

These alterations, due to fissure metasomatism, are of two distinct types resulting in either epidotisation and the formation of garnet-bearing veins, or sericitation associated with the pyrite veins. Garnet-bearing veins commonly consist essentially of an outer epidote zone and an inner zone of andradite garnets, usually developed within the fissure. The garnets are often shattered and veined with quartz, calcite and ore minerals. The formation of epidote and Ca–Fe garnets is attributed to the reaction between the wall-rocks of these joints and percolating siliceous fluids containing Ca and Fe. A chemical and petrographic study of the outer margin of the epidote zone shows that the biotite hornfelses of the wall-rocks have been silicified and Al, Fe, Mg and Ca have migrated towards the fissure. The extent of epidotisation is thought to be dependent chiefly on the introduction Ca and the mobility of Al in the wall-rocks. Evidently these fissures later formed channels for low temperature hydrothermal solutions which also penetrated other later joints. Among the minerals that have been recorded from the garnet-bearing veins are quartz, calcite, pyrites, chalcopyrite, galena, blende, molybdenite, magnetite, haematite and laumontite. This assemblage is similar to that found in the granite and if the metasomatic origin of the epidote and garnet is accepted, Marr's theory (1902) that these structures represent thermally metamorphosed pre-granite metalliferous mineral veins, is untenable.

The formation of cordierite and subsequent sericitisation of the biotite hornfelses adjacent to pyrite veins is more restricted and appears to be due to the introduction of Al followed by potash metasomatism. Cordierite is unstable in the presence of excess potash and breaks down to chlorite whilst sericite forms from felspars and biotite in the hornfelsed andesites. Alteration of this type may extend ten feet from the pyrite veins, but has been recorded only from the south end of the Shap Blue Quarry. It is thought to be later than the epidotisation.

This stage was followed by a phase of low temperature hydrothermal mineralisation. In addition to the minerals recorded in the garnet-bearing veins, other species, likewise considered to be associated with the Shap Granite, occur in tensional and shear joints, faults and shatter belts. An interesting group of clay minerals including nacrite, saponite and a hydrous mica, chlorites, laumontite, pectolite and barytes were among the last minerals to be formed.

Fissure metasomatism and mineralisation is best exhibited in the Shap Blue Quarry where the following time sequence has been established:

1. Intrusion of the Shap Granite.
2. Thermal metamorphism with the introduction of Si and K into the country rocks.
3. Epidotisation and formation of garnet.
4. Sericitisation associated with the formation of pyrite veins.
5. Low temperature hydrothermal mineralisation.

A study of this quarry has revealed a number of compressional structures such as shear joints and shatter belts which transect the metasomatic bodies but which are themselves filled with hydrothermal minerals. This evidence of late movements of the granite is being correlated with structures within the granite itself.

A detailed mineralogical study of the granite will be undertaken in connection with an investigation of the trace elements in and around the Shap Granite recently begun by J. Palframan. A preliminary report (Palframan, personal communication) shows 1000 p.p.m. of tungsten in the metasomatised contact hornfelses but the figures for lead, molybdenum and bismuth are low. The only tungstates recorded from the Shap Granite are two specimens of scheelite, but the high concentration of tungsten around the granite suggests a geochemical affinity with the Skiddaw Granite.

The aureole of the Eskdale Granite is also being investigated by the writer and here it has been demonstrated that epidotisation of the Borrowdale Volcanic Series is probably due to the introduction of watery solutions and some Ca from the granite. Local chloritisation of contact hornfelses has taken place but pre-granite almandine garnets, considered by Oliver to be pyrogenetic, are probably stable in the presence of granite.

REFERENCES

GRANTHAM, D. R. 1928. The petrology of the Shap Granite. *Proc. Geol. Assoc.*, **39**, 299–331.

HARKER, A. & J. E. MARR. 1891. The Shap Granite and associated rocks. *Quart. Journ. Geol. Soc. Lond.*, **47**, 266–328.

HARKER, A. & J. E. MARR. 1893. Supplementary notes on the metamorphic rocks around the Shap Granite. *Quart. Journ. Geol. Soc. Lond.*, **49**, 359–71.

MARR, J. E. 1902. [Exhibit of specimens from a metamorphosed metalliferous vein in basic andesites near the Shap Granite.] *Quart. Journ. Geol. Soc. Lond.*, **58**, lxxx–lxxxii.

Summer Field Meeting in the Lake District

4–11 September 1954

Report by the Secretary: M. K. WELLS

Director: S. E. Hollingworth; assisted by R. J. Firman, W. B. R. King, G. H. Mitchell, R. L. Oliver and W. C. C. Rose

Received 11 October 1954

A PARTY of approximately forty members gathered at the Headquarters for the meeting, Fletchers' Hotel, Keswick, on the evening of 4 September, to hear from Professor Hollingworth some of the general features of the programme arranged for the coming week. This was concerned with the Lower Palaeozoic rocks of the Lake District inlier, and especially with the Skiddaw Slates and Borrowdale Volcanic Series.

Sunday, 5 September

(Director: Professor Hollingworth, deputising for Dr. F. M. Trotter)

As Dr. Trotter was unable to be present, at the last minute, Professor Hollingworth led the party, with assistance from Mr. T. C. Nicholas and Mr. J. W. Jackson. The itinerary included the ascent of Skiddaw, to examine those divisions of the Skiddaw Slates which include the lowest subdivision, the Loweswater Flags, in the core of the main Skiddaw anticline; the effects of metamorphism by the Skiddaw granite; and the opportunity to see views over much of the northern and central parts of the Lake District.

At 9 a.m. the party proceeded by coach to the Applethwaite main-road junction, and walked towards the foot of Skiddaw. Here the ascent was made by a comparatively easy spur immediately east of Applethwaite Gill. The lithology of slaty members of the Skiddaw Slates was examined in screes and small outcrops on the higher slopes. At first this showed no appreciable evidence of the thermal metamorphism produced by the Skiddaw granite; but towards the crest of the Skiddaw range, and below the south-eastern promontory of Little Man, slender chiastolite needles became conspicuous, and the slates were hardened and frequently spotted. The character of the cleavage was examined and found to be parallel to the bedding, as is frequently the case in the Skiddaw Series. For this reason graptolites can be found in the cleaved scree-debris. A small number of graptolites was so found in screes in Applethwaite Gill and round Little Man.

The main Skiddaw anticline, and the highest up-fold of the Skiddaw Slates anticlinorium, passes through the Skiddaw range just south-east of Little Man, and brings up rocks of the Loweswater Flags group which are well exposed in the so-called Grey Crags on the steep south-west slope of the hill. The rocks are slates interbedded with fine-grained grey sandstones. Great interest was shown in the false bedding and slump structures of the coarser bands, and in the relationship between fracture cleavage and the folding, particularly in one well-exposed, sharp anticlinal core. Jointing in the more massive sandstones fanned out over the crest of the fold and thin quartz veins had been formed both in this direction of jointing, and parallel to the bedding.

Lunch was taken on the summit of Skiddaw. Distant views were curtailed by haze, but it was possible to see the following features of interest: (1) the contrast between the extremely rugged hills to the south and east, formed by rocks of the massive Borrowdale Volcanic Series, and the smoother, often conical forms of the Skiddaw Slate hills; (2) the Caldbeck Fells, to the north-east, which seem to have escaped active ice-erosion almost entirely, and consequently have a completely different topography from the ice-plucked and scoured hills to the south of them; (3) the narrow outcrop of Borrowdale Volcanics, forming the northern flank of the Skiddaw anticlinorium, with Binsey as a prominent landmark. Immediately north of this was the low scarp feature formed by the overlying Carboniferous Limestone. Mr. Nicholas explained the significance of the Cockermouth (Lower Carboniferous) lavas, which had been regarded as part of the Borrowdale Volcanic Series at one time. This had resulted in a complete misinterpretation of the local structure in the Borrowdale rocks, and given rise to the idea that they had a very low sheet-dip.

A few members of the party made a detour to Sinen Gill, to examine outcrops of the Skiddaw Granite and its contact with the slates, while the rest of the party returned to Keswick via Latrigg or Underscar.

Monday, 6 September (Director: Professor S. E. Hollingworth)

Since the full programme for this day was curtailed by rain and low cloud in the early afternoon, the itinerary included only the ascent of Carrock Fell from Mosedale, with examination of the contact-altered Skiddaw Slates (Loweswater Flags division); a study of the several varieties of gabbros and 'granophyre' of the Carrock Fell igneous complex, as seen in an east–west traverse near the summit of the hill; the rotting and micaceous alteration of the gabbros and hornfels near the Grainsgill greisen in Brandy Gill and examination of the greisen, and other material, in the dumps of the wolfram mines.

Coach was taken to Mosedale. Soon after starting the climb of Carrock

Fell, attention was drawn to the interesting character of the broad, north–south hollow in which the villages of Mosedale and Mungrisdale are situated. Outcrops of the resistant gabbros and other rocks of the igneous complex, striking E.–W., terminate abruptly against this hollow, forming a straight line of steep crags at the end of the Carrock Fell mass. It appears that the hollow is floored by Skiddaw Slates covered by drift and by broad, flat alluvial fans where the Rivers Caldew and Glenderamackin issue from their respective valleys. These fans are cultivated but the remainder of the floor of the hollow is covered by peat bog. Reference was made to the complicated denudation history of the hollow, originally discussed by Marr.

Rising to the east, beyond the hollow, and overlying the Skiddaw Slates, are the Borrowdale Volcanics of Eycott Hill. The swing in the direction of strike between, say, Skiddaw (ENE.–WSW.) and the Eycott Hill area (NW.–SE.), with the greatest degree of curvature manifested round Carrock Fell, was commented upon, and it was suggested that emplacement of the Carrock Fell intrusion-complex was connected with this rapid change of strike.

The party approached the contact between the contorted and disturbed Loweswater Flags and the gabbro, noting a gradual hardening and increasingly lighter colour in the flags near the gabbro. Pale albite porphyroblasts become conspicuous, and at the contact the flags had entirely lost their original texture and striping, having become crystalline felspar-rich rocks which had clearly been metasomatised by reaction with the gabbro. Almandine-spessartite garnets were seen in these altered rocks. By standing on widely-spaced exposures up the hillside, members of the party were able to show the sensibly vertical character of the contact.

In addition to varieties of gabbro (generally with conspicuous ilmenite and often with easily-visible quartz), other rocks of the igneous complex were seen, including granophyres and gabbro-granophyres having a heterogeneous, blotchy appearance and a mixed origin, and 'diabase'—a dark greenish, and finer-grained, type of basic rock with hornblende as the predominant coloured mineral. The gabbro is banded in places, but does not show the features generally associated with the gravitational sorting of crystals. The character of the banding may well be related to the 'streaking-out' of an originally heterogeneous magma, or perhaps of a crystal mush, during intrusion.

The significance of inclusions of Borrowdale volcanic rocks was discussed, including the conspicuous Eycott-type of lava which contains large basic plagioclase phenocrysts. These lava fragments now lie within the intrusion at the same topographic level as country rocks which lie south of the contact and consist of Loweswater Flags low in the Skiddaw Slate succession. It appears, therefore, that the volcanic fragments must have been let down to this level either before or during the act of intrusion. The post-Borrowdale Drygill Shales (which would have been visited had weather permitted) have been downfaulted similarly, adjacent to the intrusion, and preserved several thousand feet below the general level appropriate to rocks of their stratigraphical position in this area.

Lunch was taken in the rain near the summit of Carrock Fell but fortunately members dried on returning down Brandy Gill and along the Caldew Valley to Mosedale. In Brandy Gill, deep weathering and gullying was seen in gabbro which had been hydrothermally altered after the emplacement of the Skiddaw Granite. Nearer the latter the presence of biotite was noted as a thermal alteration-product in the gabbro. Also the gabbro has been cut by a number of N.–S. quartz veins as well as suffering a local hydrothermal alteration associated with the tungsten-mineralisation of the Grainsgill area. Dumps from the mines were examined and samples of wolfram and apatite, among other minerals, were collected. The party split into two sections for tea at Mosedale, leaving there at 6 p.m. for Keswick.

Tuesday, 7 September (Director: Dr. R. L. Oliver)

The object of this excursion was to study the results of the Director's recent work on the succession of tuffs and lavas of the Borrowdale Volcanic Series which occur on the northern limb of an eastward-pitching syncline that extends ENE. through the Scafell area. The traverse selected, between Stonethwaite and the summit of Glaramara, south of Borrowdale, coincides almost exactly with the line of section shown in Fig. 1. of the accompanying paper by Dr. Oliver (p. 409).

The three main divisions of the volcanic rocks recognised by Oliver in the area are:

(3) Seathwaite Fell Group (mainly tuffs with a central hornstone formation);
(2) Airy's Bridge Group (mainly rhyolitic or rhyodacitic);
(1) Grey Knotts Group (mainly andesites).

The Grey Knotts andesites outcrop to the south of, and above, the slate belt of Honnister Crag. Lavas and tuffs younger than the Seathwaite Fell tuffs are exposed towards the core of the syncline south of Glaramara, and were therefore not examined on this traverse (*v*. Oliver, p. 411).

The party travelled up Borrowdale by coach, crossing the Falcon Crag succession of Ward and Marr and the overlying slate belt. At Stonethwaite, flinty grey non-porphyritic andesites of Grey Knotts type, containing scattered chloritised garnets, were examined. The origin of the garnets was of special interest to the party—an interest which had been stimulated by Dr. Oliver's introductory talk of the previous evening. Opinion was divided as to whether they were of igneous or metamorphic origin. Other andesitic flows were crossed in an initially steep climb from Stonethwaite. The upper parts of some of the flows of the Grey Knotts Group are flow-brecciated and are very liable to be confused with coarse, angular tuffs. Characteristic recessed weathering of the fragmental material in the flow-breccias was observed. By contrast, it is the matrices of tuffs which are usually less resistant to weathering than are their main component fragments. Near the top of the Grey Knotts Group well-bedded and graded tuffs were seen, showing slumped bedding.

The succeeding Airy's Bridge Group of flow-banded rhyolites and rhyodacites provided excellent exposures in the vicinity of Bessyboot, and particular interest was shown in probable ignimbritic rocks (Oliver, p. 408). Many specimens of these were collected and also of rhyolites containing conspicuous red garnets which are especially characteristic of this group. Cleavage, which is concentrated into narrow belts and then very well developed, and minor folds on the flank of the main syncline, were observed in this part of the traverse. On the evidence of displacement of some of these minor folds, at right-angles to their strike, it is possible to demonstrate the existence of tear-faulting.

Coarse tuffs, forming a conspicuous and easily-traced feature at the base of the Seathwaite Fell Group, provided the next point of interest. Some of the fragments appear to be well-rounded and members of the party believed they could detect imbricate bedding, suggesting aqueous deposition.

At this point the party divided, to allow one group to take tea at Seathwaite, while the other group continued to the summit of Glaramara. The first group had the exciting experience of an almost alpine descent, while the second group was able to enjoy the fine views of this most rugged part of the central Lake District for some time longer before making their descent by a less exacting route, under Dr. Oliver's guidance.

Wednesday, 8 September

(Directors: Dr. R. J. Firman and Professor W. B. R. King)

The programme for the day included visits to the Shap 'Blue' andesite quarry and the classic Shap granite quarry, under Dr. Firman's direction, in the morning, and examination and collection from the equally classic Skelgill section of highest Ordovician and lowest Silurian rocks, directed by Professor King, in the afternoon. It proved impossible to visit Wasdale Head and Shap Wells, as suggested in the published provisional programme.

The route to Shap was extended to pass along the north side of Ullswater, when members had several good views of Great and Little Mell Fell. Roadside exposures of the Mell Fell Conglomerate were seen from the coach. The position of the overlying Carboniferous Limestone and the stratigraphical significance of the conglomerate, which is rich in Bala-age fragments of rocks otherwise unrepresented in the area, were demonstrated by Professor Hollingworth.

A brief stop was made near the north-eastern end of Ullswater in order to appreciate the significance of topographic features immediately south of the lake. The rugged skyline of Barton Fell, produced by Borrowdale Volcanics, terminated at the north-western end of the hill in a smooth and gently-inclined plane surface, which from its relationship to the nearby Carboniferous is obviously an exhumed part of a sub-Carboniferous surface. Strike features formed by individual units of the Borrowdale Volcanics were seen on the steep face of Barton Fell which faces Ullswater. These were inclined downwards towards the north-west and terminated obliquely against a smooth grassed area underlain by Skiddaw Slates, outcropping at the foot of the lower slopes. It was suggested that these features might prove to be significant in connection with the possibility of disharmonic fold-relations between the slates below and the more competent volcanics above.

Dr. Firman's demonstration of the interesting metamorphism of amygdaloidal Borrowdale andesites in the Shap 'Blue' quarry, and of the emplacement of two sets of veins with accompanying metasomatism, was closely followed, despite sharp squalls. All the rocks within the quarry form part of the aureole of the Shap granite, and the metamorphic effects are most intense on the south wall of the quarry, nearest the granite. A summary of the alterations and vein-formation produced by the granite is given in the accompanying paper by Dr. Firman. The intersection of earlier epidote-garnet-bearing fissure-veins by pyrite-bearing ones (stages 3 and 4 of the time-sequence given on p. 413) was demonstrated beside the path leading down to the quarry. Striking specimens of metasomatically-altered andesite, with a very pale sericitised matrix, and bearing dark cordierite pseudomorphs, were collected from the south wall of the quarry adjacent to one of the pyritous veins.

It is unnecessary to describe the well-known rocks of the main granite quarry at Shap. After an initial introduction, in which Dr. Firman indicated the geological setting of the intrusion and the means by which it can be dated as of post-Silurian and pre-Carboniferous age, the party split into small groups. Interest was shown in reddening, due to pneumatolysis along the master joints and in the mineral coatings on some joint faces; also in the rounded xenoliths, probably derived from Borrowdale andesites, which contain pink and often white-rimmed felspar porphyroblasts, comparable in all respects with the felspar phenocrysts of the enclosing granite (or more properly, adamellite).

Lunch was eaten in the coach *en route* for Kendal and Ambleside, where

Professor King met the party. A stop was made on the path to the famous lower footbridge locality of Skelgill (Skelghyll) at Jenkyn's Crag, from whence a good view was obtained across Windermere and where the geology was outlined by Professor King and Mr. Nicholas.

A considerable time was spent in following details of the succession of the dark and highly fossiliferous Stockdale Shales at the type-locality of the Skelgill Beds of the lower footbridge (Marr and Nicholson, 1888, especially p. 661). The succession is:

Brathay Flags, etc.
Stockdale Shales $\begin{cases}\text{Browgill Beds}\\ \text{Skelgill Beds}\end{cases}$
Ashgill Shales

At this locality the Skelgill Beds rest conformably on the highest Ordovician strata represented by the Ashgill Shales. An impure nodular limestone marks the top of the latter and is followed by the *Atrypa flexuosa* Bed, a limestone bed, one foot thick, which outcrops immediately below the bridge. An abundant collection of graptolites, in a fair state of preservation, was obtained from the succeeding bluish-black somewhat calcareous shales (*Dimorphograptus* beds, yielding many specimens of *Climacograptus*). The main part of the succession of Skelgill Beds was examined in a cliff-section above the bridge and by the footpath on the left bank of the Gill looking downstream. The beds are graptolitic shales, with intervening nodular calcareous mudstones. The latter are characterised by a somewhat sparse shelly fauna including trilobites, but the main interest centres upon graptolites which included specimens in full relief from the *Monograptus fimbriatus* Zone. A few feet above this, and above bluish mudstones, occurs another richly-fossiliferous horizon in the *M. argenteus* Zone, including a quarter-inch to half-inch green band, referred to as the 'Green Streak'. The main interest in the latter is its persistence at the same horizon over a very wide area. Professor King indicated correlations between the beds being examined and those of similar age outside the Lake District. Time did not permit an equally detailed examination of the upper Skelgill Beds and the Browgill Beds. At the upper footbridge, Ashgillian limestones were seen again, bearing a number of very large specimens of *Orthoceras*, which were left intact at the request of the Director. Attempts to find trilobites in outcrops above the bank of the stream were not successful.

At this point Mr. Hayward thanked Professor King very warmly for leading the party over the Skelgill sections.

Thursday, 9 September (Director: Mr. W. C. C. Rose)

The original object of this excursion was to examine the Skiddaw Slates, their structure, and their metamorphism to the Blakefell Mudstone type of lithology, in country west and south-west of Skiddaw. Due to high wind and rain the programme had to be so changed that the Blakefell Mudstones were not seen and the proposed climb to Causey Pike and Outerside had to be abandoned.

The party left the coach at Braithwaite and followed a path to High Coledale, from where Mr. Rose demonstrated the position of an important low-angle fault below the summit of Causey Pike (see Fig. 1 in accompanying paper). It was considered inadvisable to study this at closer quarters in view of the weather. Returning to Braithwaite, the party then examined exposures in the Mosser–Kirkstile Slates of the Skiddaw Series, on the road to Whinlatter Pass. Successful attempts were made to correlate the pitch of minor structural features such as bedding/cleavage intersections, with the pitch of the complex Braithwaite syncline as deduced from the six-inch map. In addition, some graptolites were found in a small quarry at Knot Head. After lunch at Scaw Crag quarry, beyond the summit of Whinlatter Pass, members examined Loweswater Flags which are striped and show good sedimentation structures, including an excellent example of the gouging of grooves in beds beneath slumped units. Graptolites were found in abundance, especially in the case of one well-exposed bedding-plane.

The route then led through Cockermouth to Watch Hill, where the party left the coach to examine an exposure of felsite with columnar jointing, near the crest of the hill. The felsite is of considerable interest because, repeatedly, it has been identified as a sandstone from the evidence of thin-sections. In the field, the distinctive polygonal jointing leaves little doubt as to its igneous origin; but without careful examination it is not possible to say whether it is intrusive or extrusive. Despite a high wind, Mr. Jackson was able to demonstrate that the top of the felsite had been eroded, and that pebbles of contemporary rocks rested in pockets in the irregular surface so formed. This proves that the felsite must be a lava of the same age as the Watch Hill Grits with which it is associated. The stratigraphical position of the Watch Hill Grits was discussed. Although their outcrops lie close to the Borrowdale Volcanics, thus suggesting that they are relatively high in the Skiddaw Slate succession, it is also possible that they may correspond to the Loweswater Flags. Complex folding has caused a frequent repetition of outcrops of the latter in other parts of the area, as indicated in Fig. 1 of the accompanying paper by Mr. Rose.

The next feature to be examined was the Embleton diorite intrusion in the Skiddaw Slates, which was seen in a quarry four miles east of Cockermouth and demonstrated by Mr. Jackson. The intrusion is one of a number of small igneous bodies scattered throughout the western part of the Skiddaw Slates area. This one is well-exposed in the quarry, showing steeply-inclined upper and lower surfaces concordant with the surrounding slates. The intrusion appears to have the form of a lenticular mass about a hundred feet in thickness and of no great lateral extent. Beneath the foot-wall the slates have been bleached and spotted, and within a distance of two or three feet from the contact they are sharply buckled into a drag-fold. There was some discussion as to whether this folding was produced during, or before the act of intrusion of the diorite into previously-deformed slates, or whether it was a consequence of the contrasting behaviour of the competent diorite and incompetent slates when they were simultaneously folded. The general opinion appeared to be that the intrusion preceded this local folding of the Skiddaw Slates.

Tea was taken at the Swan Hotel, beside Bessenthwaite Lake, at the foot of the famous Barf screes, long noted for graptolites of very wide stratigraphical range. These last appear to have been derived from only a very limited thickness of the slates which outcrop above the screes. Unfortunately, renewed rain prevented any collecting at this locality.

In the evening the customary informal discussion was led by Dr. Mitchell, after which Mr. H. A. Hayward, who was acting on behalf of the President of the Association, warmly thanked Professor Hollingworth for all he had done as organising director of the Field Meeting, and also the individual directors of each day's excursion. Thanks were also accorded to Mr. Nicholas and Mr. Jackson for the help each had given so freely in an unofficial capacity.

Friday, 10 September (Director: Dr. G. H. Mitchell)

The chief aims of this excursion were to examine the Coniston Limestone and basal conglomerate which rests unconformably on the Borrowdale Volcanic Series near Coniston, and then to traverse the latter by climbing to Coniston Old Man.

The route to Coniston was by Thirlmere, Grasmere, Rydal Water and past the north end of Windermere. A stop was made at a quarry between Grasmere and Rydal Water to examine slaty, fine-grained tuffs characteristic of parts of the Borrowdale Volcanics. Although no bedding was visible in the quarry faces, some of the debris showed excellent banding, graded bedding and evidence of slumping.

At the head of Windermere, Professor Hollingworth described some of the results of research carried out by the Freshwater Biological Association on the lake-deposits of Windermere. It was interesting that evidence from cores in the lake-floor sediments reveals strong climatic fluctuations covering a period since the main retreat of the ice; a period during which denudation-processes on land have had little time to produce decipherable effects.

Continuing through an attractive valley past Avonside and down into Yewdale, Mr. Nicholas demonstrated the position of two of the major tear-faults characteristic of this area. These faults displace the Coniston Limestone and the underlying unconformable Borrowdale Volcanics. In this case a large block of the volcanic rocks had been so moved that it projected well to the south of the Coniston Limestone–Borrowdale Volcanics junction. It is interesting that this fault dies out rapidly in the Silurian rocks to the south, possibly as a result of heading-off by a major strike-fault.

The party left the coach at Coniston and walked past the Railway Station, when Dr. Mitchell demonstrated the general relationship between the Borrowdale Volcanics and the Coniston Limestone. He outlined the local succession in the former and pointed out that, although the two formations had a parallel strike near Coniston, the strike of the Borrowdales turned through a right-angle farther south-west, so that the limestone series rested on the volcanics with a marked discordance. Under the guidance of Mr. Nicholas the party then crossed the Brathay Flags, the Stockdale Shales (not seen), and the Coniston Limestone with its basal conglomerate. A few graptolites were seen in the flags exposed beside the road. The Coniston Limestone was examined in a number of small crags above Mealy Gill and was seen to consist of lenses of somewhat impure fossiliferous limestone, interbedded with shaly bands. A rather tortuous route was then taken to the north-east, in the direction of Church Beck, and following the strike of the basal conglomerate of the Coniston Series. The latter was seen in a number of excellent exposures of the actual unconformity. In some places this coarse conglomerate, consisting of fragments of the underlying volcanics, lies in joint-controlled depressions in the volcanic rocks.

In the valley of Church Beck, there was considerable discussion on the relative importance of pre-Glacial rejuvenation-steps and Glacial erosion-steps in the valley floor. The effects of ice-action were very apparent, not only in such major topographic features, but also in glacial striae and polishing. It had been intended to walk up the valley towards Coniston Old Man in order to traverse part of the succession of this southern occurrence of the younger members of the Borrowdale Volcanic Series (Mitchell, 1940), but heavy rain made this impossible. The main interests in the volcanic rocks were provided by two exposures near the path and stream. In the first, an amygdaloidal andesite lava made an intricate contact with a well-bedded member of the Yewdale Tuffs (tentatively interpreted as the effect of the shallow burrowing of a flow into original ash), and in the second, perlitic texture could still be seen in a once-glassy andesite (in the Wrengill Andesites). After lunch in the relative shelter of the Lower Blue Slate quarry the party returned to Coniston while the Director and his son were last seen disappearing in a curtain of mist on their way over the hills to Ulpha.

This account should not end without recording how much pleasure and geological interest was extracted from two of the wettest days (9 and 10 September) of a memorably wet summer by a determined party of the Association under continuously cheerful Directors.

REFERENCES

HOLLINGWORTH, S. E. 1938. Carrock Fell and adjoining areas. *Proc. Yorks. Geol. Soc.*, **23** (for 1937), 108–18.

MARR, J. E. & H. A. NICHOLSON. 1888. The Stockdale Shales. *Quart. Journ. Geol. Soc. Lond.*, **47**, 654–732.

MITCHELL, G. H. 1940. The Borrowdale Volcanic Series of Coniston, Lancashire. *Quart. Journ. Geol. Soc. Lond.*, **96**, 301–19.

Field Meeting at Sevenoaks, Kent

25 September 1954

Report by the Director: R. A. MILBOURNE

Received 6 October 1954

ABOUT twenty-five members and friends assembled at Bat and Ball Railway Station and from there proceeded to the Sevenoaks Brick Company's Clay Pit at Greatness Lane, where Lower and Basal-Upper Gault (Middle and Upper Albian) are worked for brick-making.

The Director gave a brief outline of the succession exposed and indicated the best horizons for collecting fossils.

Correlation with the standard Gault succession at Folkestone, though not yet completed in detail, has shown that the following ammonite-horizons are present in the Greatness Lane Gault.

ZONES	SUBZONES
Mortoniceras inflatum	*orbignyi*
Euhoplites lautus	*cristatum*
	lautus-nitidus
	subdelaruei
Hoplites dentatus-spathi	*niobe*
	intermedius
	dentatus

The *daviesi* Subzone of the *E. lautus* Zone is absent.

The Gault at Greatness Lane shows several stratigraphical peculiarities, when compared with the Folkestone Gault, and these will be dealt with in a forthcoming paper.

Mr. Milbourne exhibited specimens of the new ammonite, *Falciferella milbournei* Casey (Casey, 1954), which he recently discovered in the *intermedius* Subzone of the Greatness pit.

After some very successful collecting by all present, the President, Dr. L. R. Cox, proposed a vote of thanks to the Director, and the party dispersed.

REFERENCES

CASEY, R. 1954. *Falciferella*, a new genus of Gault Ammonites, with a review of the family Aconeceratidae in the British Cretaceous. *Proc. Geol. Assoc.*, **65**, 262–77.

JUKES-BROWNE, A. J. 1900. The Cretaceous Rocks of Britain, I, Gault and Upper Greensand of England. *Mem. Geol. Surv.*

SPATH, L. F. 1923–43. A Monograph of the Ammonoidea of the Gault. *Mon. Palaeont. Soc.*, London.

WRIGHT, C. W. & H. D. THOMAS. 1946. Notes on the Geology of the country round Sevenoaks. *Proc. Geol. Assoc.*, **57**, 315–21.

Index to Volume 65

Page

Aconeceras nisoides (Sarasin) ... 270
Aconecoratidae, review of the family of, in the British Cretaceous 267
Aconeceras sp. nov.... 272
AGER, D. V. The genus *Gibbirhynchia* in the British Domerian 25
AKAAD, M. K. *see* PITCHER, W. S., R. L. CHEESMAN & Others
Alabamina scitula Bandy 165
Alum Bay, London Clay Foraminifera 171
Ammodiscus incertus (d'Orbigny) ... 132
—— *finlayi* Parr 132
—— sp. 132
Ammonites, Gault, *Falciferella*, a new genus of 262
ANDERSON, J. G. C., & Others. Field Meeting in South Wales (Cardiff District)... 333
——. *see* PITCHER, W. S., R. L. CHEESMAN & Others.
Annual Report of the Council for 1953 64
Anomalina flintii Cushman... ... 133
—— *globulosa* Chapman & Parr ... 133
—— *perthensis* Parr 133
Aplites, Chemical considerations ... 108
——, Origin of 95
——, Petrological characters of ... 95
——, Structural considerations ... 104
ARKELL, W. J. Three complete sections of the Cornbrash ... 115
BADEN-POWELL, D. F. W. Note on the age of the Holderness shells. Summer Field Meeting in East Yorkshire: Appendix B ... 327
Baggina bradyi (Brotzen) 163
BIGBY, GRACE [Obituary] ... 85
BIGOT, ALEXANDRE [Obituary] 86
BISAT, W. S. (& V. WILSON, C. W. WRIGHT, J. E. HEMINGWAY, H. C. VERSEY). Summer Field Meeting in East Yorkshire... 313
——. Additional records of mollusca from the Dimlington area, and the relation of the beds to the Bridlington Crag. Summer Field Meeting in East Yorkshire: Appendix A.... 325

Page

BISHOP, A. CLIVE *see* WELLS, A. KINGSLEY
Blean, Relief and drainage evolution of 52
BLUNDELL, R. C. K. *see* ANDERSON, J. G. C.
BLYTH, F. G. H. The southern margin of the Cairnsmore of Fleet granite at the Clints of Dromore, Galloway 224
Bolivina advena Cushman ... 138
—— *moodysensis* Cushman & Todd 138
—— *punctata* d'Orbigny 139
Bolivinopsis catinata (d'Orbigny) ... 166
—— *expansa* (Plummer) 166
BOWEN, R. N. C. Foraminifera from the London Clay 125
Bracklesham Beds near Sopley, Hampshire 251
BRADSHAW, R. Field Meeting in the Caterham–Godstone district 23
—— (M. ROQUES & P. LAPADU-HARGUES). Report on Summer Field Meeting in the Massif Central 278
Bridlington Crag, relation of, to beds at Dimlington 325
Bulimina ovata d'Orbigny 136
—— *ovula* d'Orbigny 137
BURCHELL, J. P. T. Loessic Deposits in the Fifty-foot Terrace post-dating the Main Combe Rock of Baker's Hole, Northfleet, Kent 256
Cairnsmore of Fleet granite at the Clints of Dromore, Galloway ... 224
CARRECK, J. N. (& A. G. DAVIS). Field Meeting at Keston, Downe, Kent, and Visit to the Darwin Memorial Rooms at Downe House 338
—— (& M. P. KERNEY). Notes on some Holocene Chalk Rainwashes at Cudham and Keston, near Downe, Kent. Appendix to Report on Field Meeting at Keston, Downe, Kent, and Visit to the Darwin Memorial Rooms at Downe House 340
CASEY, R. *Falciferella*, a new genus of Gault Ammonites, with a review of the family Aconeceratidae in the British Cretaceous ... 262

Page

Caterham–Godstone district, Field Meeting 23

Channel Islands, Aplites 95

CHEESMAN, R. L. (& W. S. PITCHER) and Others. Report on Summer Field Meeting in North-West Ireland with an Introductory Note on the Geology 345

Chilostomelloides oviformis (Sherborn & Chapman) 140

CHRISTIE, J. M. (in discussion) ... 220

Cibicidella variabilis (d'Orbigny) ... 134

Cibicides delicatus Le Roy 134

—— *lobatulus* (Walker & Jacobs) ... 134

—— *praecursorius* (Schwager) ... 136

—— *pseudoungerianus* (Cushman) 136

—— *pygmeus* (Hantken) var. *almaensis* Samoilova 136

—— *vulgaris* (Plummer) 136

CLARKE, B. B. (& J. D. LAWSON). Field Meeting at Hereford (Midland Group) 374

Clavalina parisiensis d'Orbigny ... 167

Clints of Dromore, Galloway, Cairnsmore of Fleet granite at ... 224

COLEMAN, A. The relief and drainage evolution of the Blean... 52

Coombe Rock of Baker's Hole, Northfleet, Kent 256

Cornbrash 115

Cornuspira involvens (Reuss) ... 162

—— *lewisensis* Beck 162

Cretaceous, British, a review of the family Aconeceratidae in the ... 267

CROFT, W. N. [Obituary] ... 87

CURRY, DENNIS. Field Meeting at Whitecliff Bay, Isle of Wight... 182

DAVIS, A. G. (& J. N. CARRECK). Field Meeting at Keston, Downe, Kent, and Visit to the Darwin Memorial Rooms at Downe House 338

—— (& G. F. ELLIOTT). Field Meeting in Sheppey 383

Dentalina bradyensis (Dervieux) ... 144

—— *multilineata* Bornemann ... 144

—— *obliquata* Reuss 145

—— *pauperata* d'Orbigny 145

—— *sherborni* sp. nov. 145

Devon, North, Field Meeting to Lynton 178

Dimlington area, mollusca from ... 325

Discorbis chapmani sp. nov. ... 164

DOLLAR, A. J. (in discussion) ... 249

Domerian, British 25

Page

Donations to the Library 83

Drainage evolution and relief of the Blean 52

Dromore, Clints of, Galloway ... 224

East Yorkshire, Summer Field Meeting in 313

ELLIOTT, G. F. (& A. G. DAVIS). Field Meeting in Sheppey ... 383

——. Note on the varying condition of the Sheppey Cliffs and Foreshore. Appendix to Report on Field Meeting in Sheppey ... 384

Elphidium concinnum Nicol ... 159

Eponides punctulata (d'Orbigny) ... 165

—— *umbonata* (Reuss) 165

EVANS, P. Field Meeting in the Vale of St. Albans 18

EVANS, W. B. *see* LEITCH, D.

Exhibits (Reunion), List of ... 78

FAIRBAIRN, P. E. A Temporary Exposure in the Bracklesham Beds near Sopley, Hampshire ... 251

Falciferella, a new genus of Gault Ammonites, with a review of the family Aconeceratidae in the British Cretaceous. By R. CASEY 262

—— *milbournei gen. et* sp. nov. ... 273

Field Meetings 1953 ... ...65, 80

——, The Geologists' Association and its 1

Fifty-foot Terrace post-dating the Main Coombe Rock of Baker's Hole, Northfleet, Kent, Loessic Deposits in 256

FIRMAN, R. J. Note on Metasomatic changes in the rocks adjacent to the Shap Granite. Appendix to The Geology of the Lake District—a Review, by S. E. Hollingworth 412

Foraminifera from the London Clay. By R. N. C. Bowen ... 125

Foulerton Award 67, 75

GARRETT, P. A. Field Meeting at Abberley, Worcestershire (Midland Group) 372

Gaudryina (*Gaudryina*) *ashfordi* sp. nov. 167

Gault Ammonites, *Falciferella*, a new genus of 262

Genus *Gibbirhynchia* in the British Domerian. By D. V. AGER ... 25

Geologists' Association and its Field Meetings. By G. W. HIMUS 1

Page

GEORGE, T. NEVILLE (& D. LEITCH) and Others. Field Meeting in South Wales (Swansea District) 328
——. *see* PITCHER, W. S., R. L. CHEESMAN and Others.
Gibbirhynchia amalthei (Queenstedt) 32
—— *gibbosa* S. S. Buckman ... 36
—— *micra* sp. nov. 38
—— *muir-woodae* sp. nov.... ... 40
—— *northamptonensis* (Davidson) 42
—— *thorncombiensis* (S. S. Buckman) 43
—— *tiltonensis* sp. nov. 46
Glandulina conica Neugeboren ... 163
Globigerina bulloides d'Orbigny ... 140
—— *dubia* Egger 141
—— *trilocularis* d'Orbigny ... 141
Globorotalia boueana (d'Orbigny)... 141
Globulina gibba (d'Orbigny) ... 163
—— *lactea* (Walker & Jacob) ... 163
GRIFFITH, J. A Technique for the removal of skeletal remains from bone-bed 123
Greensand, Lower, in East Kent ... 185
Gyroidina soldanii d'Orbigny ... 164
—— sp. 164
Haplophragmoides discus (Rzehak) 158
HARDIE, W. G. The Silurian rocks of Kendal End, near Barnt Green, Worcestershire 11
HAWARD, F. J. N. [Obituary] ... 88
HEMINGWAY, J. E. (& V. WILSON, C. W. WRIGHT, H. C. VERSEY, W. S. BISAT). Summer Field Meeting in East Yorkshire... 313
HIMUS, G. W. The Geologists' Association and its Field Meetings. Presidential Address ... 1
Hindhead neighbourhood, Field Meeting 175
Holderness shells, Note on the age of 327
HOLLINGWORTH, S. E. The Geology of the Lake District—a review, with appendices by R. J. FIRMAN, R. L. OLIVER & W. C. C. ROSE 385
—— and Others. Summer Field Meeting in the Lake District ... 415
Ireland, North-West, Summer Field Meeting in, with an Introductory Note on the Geology ... 345
Jersey, Channel Islands, Aplites ... 95
Kendal End, Worcestershire ... 11

Page

Kent, The Lower Greensand in East 185
KERNEY, M. P. (& J. N. CARRECK). Notes on some Holocene Chalk Rainwashes at Cudham and Keston, near Downe, Kent. Appendix to Report on Field Meeting at Keston, Downe, Kent, and Visit to the Darwin Memorial Rooms at Downe House 340
KIDSON, C. (& SCOTT SIMPSON). Field Meeting Whitsun 1953 at Lynton, North Devon ... 178
KING, W. B. R. *see* HOLLINGWORTH, S. E., and Others.
KIRKALDY, J. F. & F. A. MIDDLEMISS. Field Meeting in the Hindhead neighbourhood 175
Lagena globosa (Montagu)... ... 142
—— *hexagona* (Williamson) ... 143
—— *laevis* (Montagu) 143
—— *oxystoma* Reuss 143
—— *salinensis* Howe 143
—— *sphaeroidalis* (Fornasini) ... 143
—— *striata* (d'Orbigny) 143
—— *sulcata* (Walker & Jacob) ... 144
LAPADU-HARGUES, P. (M. ROQUES & R. BRADSHAW). Report on Summer Field Meeting in the Massif Central ... 278
LAWSON, J. D. (& B. B. CLARKE). Field Meeting at Hereford (Midland Group) ... 374
LEITCH, D. (& T. NEVILLE GEORGE) and Others. Field Meeting in South Wales (Swansea District) 328
LEMON, G. G. *see* PITCHER, W. S., R. L. CHEESMAN and Others.
Lenticulina articulata (Reuss) ... 145
—— *Cushmani* (Galloway & Wissler) var. *procedenus* Coryell & Mossman 146
—— *degolyeri* (Plummer) ... 146
—— *ellisori* sp. nov. 146
—— *flexuosa* (Sherborn & Chapman) 146
—— *inornata* (d'Orbigny) 147
—— *limbosa* (Reuss) 147
—— *mayi* (Cushman & Parker) ... 147
—— *megalopolitana* (Reuss) ... 148
—— *navis* (Bornemann) 148
—— *rotulata* (Lamarck) 148
—— *splendens* (Sherborn & Chapman) 148

Page

Lenticulina texanus (Cushman & Applin) 148
—— *umbonata* (Reuss) 148
—— *washingtonensis* Beck ... 149
Library, List of donations 83
Loessic Deposits in the Fifty-foot Terrace post-dating the Main Coombe Rock of Baker's Hole, Northfleet, Kent. By J. P. T. BURCHELL 256
London Clay, Foraminifera from ... 125
Lower Greensand in East Kent. By G. A. WORRALL 185
Lynton, North Devon, Field Meeting... 178
McINTYRE, D. B. The Moine Thrust—its discovery, age and tectonic significance 203
Main Coombe Rock of Baker's Hole, Northfleet, Kent, Loessic Deposits in the Fifty-foot Terrace post-dating the 256
Marginulina crepidula (Fichtel & Moll) 149
—— *enbornensis* sp. nov. 149
—— *glabra* d'Orbigny 151
MARTIN, E. C. Field Meeting at Highdown Hill, Clapham, and Storrington, West Sussex ... 377
Massif Central, Summer Field Meeting in 278
MICHEL, R. *see* ROQUES, M. and Others.
MIDDLEMISS, F. A. (& J. F. KIRKALDY). Field Meeting in the Hindhead Neighbourhood ... 175
Midland Group, Report 81
MILBOURNE, R. A., Field Meeting at Sevenoaks, Kent 426
MITCHELL, G. H. *see* HOLLINGWORTH, S. E., and Others.
Moine Thrust, The—its discovery, age, and tectonic significance. By D. B. McINTYRE 203
Mollusca from the Dimlington area 325
Nodogenerina hirsuta (Soldani) ... 142
Nodosaria acuminata Hantken ... 151
—— *adolphina* (d'Orbigny) ... 152
—— *arundinacea* (Costa) 152
—— *consobrina* (d'Orbigny) ... 152
—— *latejugata* Gümbel 153
—— *longiscata* d'Orbigny 153
—— *natchitochensis* (Howe) ... 154
—— *obliqua* (Linné) var. *torsa* Koch 154
—— *obliquestricata* (Reuss) ... 154
—— *ovulata* Sherborn & Chapman 154

Page

Nodosaria pariana Hedberg ... 154
—— *raphanistrum* (Linné) ... 154
—— *soluta* (Reuss)... 154
—— sp. 154
—— *spinescens* (Reuss) 155
—— *spinulosa* (Montagu) ... 155
—— *subcanaliculata* (Neugeboren) var. *spinescens* nov. 155
—— *vertebralis* (Batsch) 155
Nonion applini Howe & Wallace ... 159
—— *elongatum* (d'Orbigny) ... 160
—— *scaphum* (Fichtel & Moll) ... 160
—— *umbilicatulus* (Montagu) ... 160
Nonionella auris (d'Orbigny) ... 160
—— *jacksonensis* Cushman ... 160
—— sp. 162
Northamptonshire, Cornbrash of... 120
North-east Lancashire Group, Report 81
Northfleet, Kent, Loessic Deposits in the Fifty-foot Terrace post-dating the Main Coombe Rock of Baker's Hole 256
North Staffordshire Group, Report 82
North-West Ireland, Summer Field Meeting in, with an Introductory Note on the Geology 345
NUTTALL, E. [Obituary]... ... 89
Obituary Notices, 1953, Bigby, G., Bigot, A., Croft, W. N., Haward, F. J. N., Nuttall, E., Smyth, L. B., White, E., Wrigley, A. G. ... 85
OLIVER, R. L. Note on the Succession in the region around the head of Borrowdale, Cumberland. Appendix to The Geology of the Lake District—a review, by S. E. Hollingworth 407
Orbulina universa d'Orbigny ... 141
Origin of Aplites with special reference to these in Jersey, Channel Islands. By A. KINGSLEY WELLS & A. CLIVE BISHOP... 95
Orthomorphina ambigua (Neugeboren) 142
OSWALD, D. H. *see* PITCHER, W. S., R. L. CHEESMAN and Others.
OWEN, T. R. *see* LEITCH, D.
Oxshott, Surrey, London clay Foraminifera 171
Palaeoecology of Eocene Foraminifera 169
PANDE, I. C. *see* PITCHER, W. S., R. L. CHEESMAN and Others.

Page
PETERLONGO, M. *see* ROQUES, M. and Others
PITCHER, W. S. (in discussion) ... 250
—— (& R. L. CHEESMAN) and Others. Report of Summer Field Meeting in North-West Ireland with an Introductory Note on the Geology 345
PITCHER, W. S. (& R. L. CHEESMAN) and Others. Summer Field Meeting in North-West Ireland with an Introductory Note on the Geology ... 345
Planularia sp. 156
Planulina anglica sp. nov. 133
Protaconeceras gen. nov. 269
—— spp. nov. 270
Pseudoclavulina anglica Cushman ... 169
Pseudoglandulina laevigata (d'Orbigny) 156
—— *nucula* (Neugeboren) 156
—— *obtusissima* (Reuss) 157
—— *ovata* (Cushman & Applin) ... 157
—— *tumida* sp. nov. 157
Pullenia bulloides (d'Orbigny) ... 139
—— *quinqueloba* (Reuss) 139
—— —— var. *quadriloba* Reuss ... 139
—— *salisburgi* R. E. & K. C. Stewart 140
—— *trinitatensis* Cushman & Stainforth 140
Pyrulina gutta d'Orbigny 163
Quinqueloculina akneriana d'Orbigny 158
—— *arctica* Cushman 159
—— *imperialis* Hanna & Hanna var. *porterensis* Rau 159
—— *ludwigi* Reuss 159
READ, H. H. *see* PITCHER, W. S., R. L. CHEESMAN and Others.
Relief and drainage evolution of the Blean. By A. COLEMAN ... 52
Report of the session 1953... ... 74
Reunion, List of exhibits 78
RICHARDS, E. *see* ANDERSON, J. G. C.
ROQUES, M. (P. LAPADU-HARGUES & R. BRADSHAW). Report on Summer Field Meeting in the Massif Central 278
ROSE, W. C. C. The Sequence and Structure of the Skiddaw Slates in the Keswick–Buttermere Area. Appendix to The Geology of the Lake District—a review, by S. E. Hollingworth.
Rotalia beccarii (Linné) 166

Page
St. Albans, Vale of, Field Meeting 18
?*Sanmartinoceras* (*Sanmartinoceras*) sp. 273
Sanmartinoceras (Theganeceras) cf. *falcatum* (v. Koenen) 272
Saracenaria italica Defrance var. *spinulosa* Sherborn & Chapman 157
SHACKLETON, R. M. *see* PITCHER, W. S., R. L. CHEESMAN and Others.
Sheppey, Isle of, London Clay Foraminifera 170
Silurian rocks of Kendal End, near Barnt Green, Worcestershire. By W. G. HARDIE 11
SIMPSON, BRIAN. Report on Field Meeting in South Wales ... 328
SIMPSON, SCOTT & C. KIDSON. Field Meeting, Whitsun 1953, at Lynton, North Devon ... 178
Skeletal remains from bone-bed, Removal of 123
SMYTH, L. B. [Obituary] 90
Somerset, Cornbrash of 115
Sopley, Hampshire, Bracklesham Beds near 251
South Wales, Field Meeting in ... 328
SUTTON, J. (in discussions) 221, 249
Technique for the removal of skeletal remains from bone-bed. By J. GRIFFITH 123
Textularia broussardi Howe & Wallace 166
—— *lontensis* Lalicker 166
—— *oveyi* sp. nov. 166
—— *porrecta* Brady 167
—— *secasensis* Lalicker & McCulloch 167
The Geologists' Association and its Field Meetings. Address by the President, G. W. Himus 1
Three complete sections of the Cornbrash. By W. J. ARKELL... 115
TOZER, C. F. *see* PITCHER, W. S., R. L. CHEESMAN and Others.
Triloculina pulchella d'Orbigny ... 159
Tristix sp. 157
Trustees of the Association ... 67
Uvigerina aculeata d'Orbigny var. *asperula* czyzek 137
—— *canariensis* d'Orbigny ... 137
—— *jacksonensis* Cushman ... 138
—— *pigmea* d'Orbigny 138
Vale of St. Albans, Field Meeting ... 18
Valvulineria barnardi sp. nov. ... 165

Page

Valvulineria byramensis (Cushman & Todd) 165
Verneuilina carinata Hermes ... 169
VERSEY, H. C. (& V. WILSON, C. W. WRIGHT, J. E. HEMINGWAY, W. S. BISAT). Summer Field Meeting in East Yorkshire 313
Wales, South, Field Meeting in ... 328
WEISS, L. E. (in discussion) ... 221
WELLS, A. KINGSLEY & A. CLIVE BISHOP. The origin of aplites with special reference to those in Jersey, Channel Islands 95
WELLS, M. K. Report on Summer Field Meeting in the Lake District 415
WHITE, ELSIE [Obituary] ... 91
Whitecliffe Bay, Isle of Wight, Field Meeting 182
——, London Clay, Foraminifera... 171
Whitsun Field Meeting, 1953, at Lynton, North Devon 178

Page

WHITTEN, E. H. T. (in discussion) 250
—— *see* PITCHER, W. S., R. L. CHEESMAN and Others.
Wight, Isle of, Whitecliffe Bay ... 182
WILKINSON, P. (in discussion) ... 222
WILSON, GILBERT (in discussion) 220
WILSON, V. (& C. W. WRIGHT, J. E. HEMINGWAY, H. C. VERSEY, W. S. BISAT). Summer Field Meeting in East Yorkshire... 313
WORRALL, G. A. The Lower Greensand in East Kent ... 185
WRIGHT, C. W. (& V. WILSON, J. E. HEMINGWAY, H. C. VERSEY & W. S. BISAT). Summer Field Meeting in East Yorkshire... 313
WRIGLEY, A. G. [Obituary] ... 91
Yorkshire, East, Summer Field Meeting in 313